ANTISENSE OLIGONUCLEOTIDE COMPOSITIONS AND METHODS FOR THE MODULATION OF JNK PROTEINS

INTRODUCTION

This application is a continuation-in-part of U.S. Application No. 09/396,902 filed on September 15, 1999, which is a continuation-in-part of U.S. Application No. 09/287,796, filed on April 7, 1999, now issued U.S. Patent No. 6,133,246, which is a continuation-in-part of U.S. Application Serial No. 09/130,616 filed on August 7, 1998 which is a continuation-in-part of U.S. Application Serial No. 08/910,629 filed on August 13, 1997, now issued U.S. Patent No. 5,877,309.

FIELD OF THE INVENTION

The present invention provides compositions and methods for detecting and modulating levels of Jun N-terminal kinases (*JNK* proteins), enzymes which are encoded by *JNK* genes. In particular, the invention relates to antisense oligonucleotides specifically hybridizable with nucleic acids encoding JNK proteins. It has been found that antisense oligonucleotides can modulate the expression of these and other JNK proteins, kinases which were initially discovered due to their ability to catalyze the phosphorylation of the c-Jun subunit of transcription factor AP-1 and thereby increase AP-1 activity. Other transcription factors, such as AT-2, are similarly activated by JNK proteins, and a variety of other cellular effectors may serve as substrates for JNK proteins (Gutta *et al.*, *Science*, **1995**, *267*, 389). In any event, transcription factor AP-1 has been implicated in abnormal cell proliferation, oncogenic transformation, and

tumor formation, development and maintenance (Volt, Chapter 15 *In: The* FOS *and* JUN *Families of Transcription Factors*, Angel and Herrlich, Eds., CBC Press, Boca Raton, FL, **1994**). Accordingly, it is believed that (1) JNK proteins are aberrantly expressed in some neoplasms and tumors with resultant increased AP-1 activity, and (2) even in abnormally proliferating cells in which a *JNK* gene is not aberrantly expressed, inhibition of *JNK* expression will result in decreased AP-1 activity and thus, inhibition of abnormal cell proliferation and tumor formation, development and maintenance. The invention is thus directed to diagnostic methods for detecting, and therapeutic methods for inhibiting, the hyperproliferation of cells and the formation, development and maintenance of tumors. Furthermore, this invention is directed to treatment of conditions associated with abnormal expression of *JNK* genes. This invention also relates to therapies, diagnostics, and research reagents for disease states or disorders which respond to modulation of the expression of JNK proteins. Inhibition of the hyperproliferation of cells, and corresponding prophylactic, palliative and therapeutic effects result from treatment with the oligonucleotides of the invention.

BACKGROUND OF THE INVENTION

Transcription factors play a central role in the expression of specific genes upon stimulation by extracellular signals, thereby regulating a complex array of biological processes. Members of the family of transcription factors termed AP-1 (activating protein-1) alter gene expression in response to growth factors, cytokines, tumor promoters, carcinogens and increased expression of certain oncogenes (Rahmsdorf, Chapter 13, and Rapp *et al.*, Chapter 16 *In: The* FOS *and* JUN *Families of Transcription Factors*, Angel and Herrlich, Eds., CBC Press, Boca Raton, FL, **1994**). Growth

factors and cytokines, such as TNFa, exert their function by binding to specific cell surface receptors. Receptor occupancy triggers a signal transduction cascade to the nucleus. In this cascade, transcription factors such as AP-1 execute long term responses to the extracellular factors by modulating gene expression. Such changes in cellular gene expression lead to DNA synthesis, and eventually the formation of differentiated derivatives (Angel and Karin, *Biochim. Biophys. Acta*, **1991**, *1072*, 129).

In general terms, AP-1 denotes one member of a family of related heterodimeric transcription factor complexes found in eukaryotic cells or viruses (*The* FOR *and* JUN *Families of Transcription Factors*, Angel and Hairlike, Eds., CBC Press, Boca Raton, FL, **1994**; Bohmann *et al.*, *Science*, **1987**, *238*, 1386; Angel *et al.*, *Nature*, **1988**, *332*, 166). Two relatively well-characterized AP-1 subunits are c-For and c-Jun; these two proteins are products of the *c-for* and *c-jun* proto-oncogenes, respectively. Repression of the activity of either *c-for* or *c-jun*, or of both proto-oncogenes, and the resultant inhibition of the formation of c-For and c-Jun proteins, is desirable for the inhibition of cell proliferation, tumor formation and tumor growth.

The phosphorylation of proteins plays a key role in the transduction of extracellular signals into the cell. Mitogen-activated protein kinases (MAPKs), enzymes which effect such phosphorylations are targets for the action of growth factors, hormones, and other agents involved in cellular metabolism, proliferation and differentiation (Cobb *et al.*, *J. Biol. Chem.*, **1995**, *270*, 14843). MAPKs (also referred to as extracellular signal-regulated protein kinases, or ERKs) are themselves activated by phosphorylation catalyzed by, *e.g.*, receptor tyrosine kinases, G protein-coupled receptors, protein kinase C (PKC), and the apparently MAPK-dedicated kinases MEK1 and MEK2. In general, MAP kinases are involved

in a variety of signal transduction pathways (sometimes overlapping and sometimes parallel) that function to convey extracellular stimuli to protooncogene products to modulate cellular proliferation and/or differentiation (Seger *et al.*, *FASEB J.*, **1995**, *9*, 726; Cano *et al.*, *Trends Biochem. Sci.*, **1995**, *20*, 117). In a typical MAP kinase pathway, it is thought that a first MAP kinase, called a MEKK, phosphorylates and thereby activates a second MAP kinase, called a MEK, which, in turn, phosphorylates and activates a MAPK/ERK or JNK/SAPK enzyme ("SAPK" is an abbreviation for stress-activated protein kinase). Finally, the activated MAPK/ERK or JNK/SAPK enzyme itself phosphorylates and activates a transcription factor (such as, *e.g.*, AP-1) or other substrates (Cano *et al.*, *Trends Biochem. Sci.*, **1995**, *20*, 117). This canonical cascade can be simply represented as follows:

MEKK -----> MEK ----> MAPK/ERK -----> transcription factor
or JNK/SAPK or other substrate(s)

One of the signal transduction pathways involves the MAP kinases Jun N-terminal kinase 1 (JNK1) and Jun N-terminal kinase 2 (JNK2) which are responsible for the phosphorylation of specific sites (Serine 63 and Serine 73) on the amino terminal portion of c-Jun. Phosphorylation of these sites potentiates the ability of AP-1 to activate transcription (Binetruy *et al.*, *Nature*, **1991**, *351*, 122; Smeal *et al.*, *Nature*, **1991**, *354*, 494). Besides JNK1 and JNK2, other JNK family members have been described, including JNK3 (Gutta *et al.*, *EMBO J.*, **1996**, *15*, 2760), initially named $p49^{3F12}$ kinase (Mohit *et al.*, *Neuron*, **1994**, *14*, 67). The term "JNK protein" as used herein shall mean a member of the JNK family of kinases, including but not limited to JNK1, JNK2 and JNK3, their isoforms (Gutta *et al.*, *EMBO J.*, **1996**, *15*, 2760) and other members of the JNK family of proteins whether they

function as Jun N-terminal kinases *per se* (that is, phosphorylate Jun at a specific amino terminally located position) or not.

At least one human leukemia oncogene has been shown to enhance Jun N-terminal kinase function (Raitano *et al.*, *Proc. Natl. Acad. Sci. (USA)*, **1995**, *92*, 11746). Modulation of the expression of one or more JNK proteins is desirable in order to interfere with hyperproliferation of cells and with the transcription of genes stimulated by AP-1 and other JNK protein phosphorylation substrates. Modulation of the expression of one or more other JNK proteins is also desirable in order to interfere with hyperproliferation of cells resulting from abnormalities in specific signal transduction pathways. To date, there are no known therapeutic agents which effectively inhibit gene expression of one or more JNK proteins. Consequently, there remains a long-felt need for improved compositions and methods for modulating the expression of specific JNK proteins.

Moreover, cellular hyperproliferation in an animal can have several outcomes. Internal processes may eliminate hyperproliferative cells before a tumor can form. Tumors are abnormal growths resulting from the hyperproliferation of cells. Cells that proliferate to excess but stay put form benign tumors, which can typically be removed by local surgery. In contrast, malignant tumors or cancers comprise cells that are capable of undergoing metastasis, *i.e.*, a process by which hyperproliferative cells spread to, and secure themselves within, other parts of the body via the circulatory or lymphatic system (see, generally, Chapter 16 *In: Molecular Biology of the Cell*, Alberts *et al.*, Eds., Garland Publishing, Inc., New York, **1983**). Using antisense oligonucleotides, it has surprisingly been discovered that several genes encoding enzymes required for metastasis are positively regulated by AP-1, which may itself be modulated

by antisense oligonucleotides targeted to one or more JNK proteins. Consequently, the invention satisfies the long-felt need for improved compositions and methods for modulating the metastasis of malignant tumors.

Prostate cancer is the most commonly diagnosed malignancy in American men. Therapy for advanced prostate cancer generally involves castration or drug therapy to remove or suppress androgens. Progression to androgen-independence inevitably occurs, associated with the development of clinical symptoms, particularly metastases to the bone, and rising serum prostate specific antigen levels. Conventional cytotoxic chemotherapy is generally ineffective (response rate below 10%) or poorly tolerated in the elderly male population.

c-jun has been shown to selectively activate androgen receptor-dependent transactivation. Consequently, c-jun has been implicated as a possible mediator of prostate tumor progression after androgen withdrawal, thus c-jun and the JNK pathway are potential chemotherapeutic targets. Bubulya et al., *J. Biol. Chem.* **1996,** *271,* 24583-24589.

JNKs have been implicated as key mediators of a variety of cellular responses and pathologies. JNKs can be activated by environmental stress, such as radiation, heat shock, osmotic shock, or growth factor withdrawal as well as by pro-inflammatory cytokines. Several studies have demonstrated a role for JNK activation in apoptosis induced by a number of stimuli in several cell types. Apoptosis, or programmed cell death, is an essential feature of growth and development, as the control of cell number is a balance between cell proliferation and cell death. Apoptosis is an active rather than a passive process, resulting in cell suicide as a result of any of a number of external or internal signals. Apoptotic cell death is characterized by nuclear condensation, endonucleolytic degradation of DNA at nucleosomal intervals ("laddering") and plasma membrane blebbing. Programmed cell death plays an essential role in, for example, immune system

development and nervous system development. In the former, T cells displaying autoreactive antigen receptors are removed by apoptosis. In the latter, a significant reshaping of neural structures occurs, partly through apoptosis.

Diseases and conditions in which apoptosis has been implicated fall into two categories, those in which there is increased cell survival (i.e., apoptosis is reduced) and those in which there is excess cell death (i.e.,apoptosis is increased). Diseases in which there is an excessive accumulation of cells due to increased cell survival include cancer, autoimmune disorders and viral infections. Until recently, it was thought that cytotoxic drugs killed target cells directly by interfering with some life-maintaining function. However, of late, it has been shown that exposure to several cytotoxic drugs with disparate mechanisms of action induces apoptosis in both malignant and normal cells. Manipulation of levels of trophic factors (e.g., by anti-estrogen compounds or those which reduce levels of various growth hormones) has been one clinical approach to promote apoptosis, since deprivation of trophic factors can induce apoptosis. Apoptosis is also essential for the removal of potentially autoreactive lymphocytes during development and the removal of excess cells after the completion of an immune or inflammatory response. Recent work has clearly demonstrated that improper apoptosis may underlie the pathogenesis of autoimmune diseases by allowing abnormal autoreactive lymphocytes to survive. For these and other conditions in which insufficient apoptosis is believed to be involved, promotion of apoptosis is desired.

In the second category, AIDS and neurodegenerative disorders like Alzheimer's or Parkinson's disease represent disorders for which an excess of cell death due to promotion of apoptosis (or unwanted apoptosis) has been implicated. Amyotrophic lateral sclerosis, retinitis pigmentosa, and epilepsy are other neurologic disorders in which apoptosis has

been implicated. Apoptosis has been reported to occur in conditions characterized by ischemia, e.g. myocardial infarction and stroke. Apoptosis has also been implicated in a number of liver disorders including obstructive jaundice and hepatic damage due to toxins and drugs. Apoptosis has also been identified as a key phenomenon in some diseases of the kidney, i.e. polycystic kidney, as well as in disorders of the pancreas including diabetes. Thatte, U. et al., 1997, Drugs *54*, 511-532. For these and other diseases and conditions in which unwanted apoptosis is believed to be involved, inhibitors of apoptosis are desired.

SUMMARY OF THE INVENTION

In accordance with the present invention, oligonucleotides are provided which specifically hybridize with a nucleic acid encoding a JNK protein. Certain oligonucleotides of the invention are designed to bind either directly to mRNA transcribed from, or to a selected DNA portion of, a *JNK* gene that encodes a JNK protein, thereby modulating the expression thereof and/or the phosphorylation of one or more substrates for the JNK protein. Pharmaceutical compositions comprising the oligonucleotides of the invention, and various methods of using the oligonucleotides of the invention, including methods of modulating one or more metastatic events, are also herein provided.

DETAILED DESCRIPTION OF THE INVENTION

Oligonucleotides may comprise nucleotide sequences sufficient in identity and number to effect specific hybridization with a particular nucleic acid. Such oligonucleotides are commonly described as "antisense." Antisense oligonucleotides are commonly used as research reagents, diagnostic aids, and therapeutic agents. It has been discovered that genes (*JNK*) encoding Jun N-terminal kinase (JNK proteins) are particularly amenable to this

approach. In the context of the invention, the terms "Jun N-terminal kinase" and "JNK protein" refer to proteins actually known to phosphorylate the amino terminal (N-terminal) portion of the Jun subunit of AP-1, as well as those that have been tentatively identified as JNK proteins based on amino acid sequence but which may in fact additionally or alternatively bind and/or phosphorylate either other transcription factors (*e.g.*, ATF2) or kinase substrates that are not known to be involved in transcription (Derijard *et al.*, *Cell*, **1994**, *76*, 1025; Kallunki *et al.*, *Genes & Development*, **1994**, *8*, 2996; Gutta *et al.*, *EMBO J.*, **1996**, *15*, 2760). More specifically, the present invention is directed to antisense oligonucleotides that modulate the JNK1, JNK2 and JNK3 proteins. As a consequence of the association between cellular proliferation and activation (*via* phosphorylation) of AP-1, other transcription factors and/or other proteins by JNK proteins, inhibition of the expression of one or more JNK proteins leads to inhibition of the activation of AP-1 and/or other factors involved in cellular proliferation, cell cycle progression or metastatic events, and, accordingly, results in modulation of these activities. Such modulation is desirable for treating, alleviating or preventing various hyperproliferative disorders or diseases, such as various cancers. Such inhibition is further desirable for preventing or modulating the development of such diseases or disorders in an animal suspected of being, or known to be, prone to such diseases or disorders. If desired, modulation of the expression of one JNK protein can be combined with modulation of one or more additional JNK proteins in order to achieve a requisite level of interference with AP-1-mediated transcription.

Methods of modulating the expression of JNK proteins comprising contacting animals with oligonucleotides specifically hybridizable with a nucleic acid encoding a JNK

protein are herein provided. These methods are believed to be useful both therapeutically and diagnostically as a consequence of the association between kinase-mediated activation of AP-1 and cellular proliferation. These methods are also useful as tools, for example, in the detection and determination of the role of kinase-mediated activation of AP-1 in various cell functions and physiological processes and conditions, and for the diagnosis of conditions associated with such expression and activation.

The present invention also comprises methods of inhibiting JNK-mediated activation using the oligonucleotides of the invention. Methods of treating conditions in which abnormal or excessive JNK-mediated cellular proliferation occurs are also provided. These methods employ the oligonucleotides of the invention and are believed to be useful both therapeutically and as clinical research and diagnostic tools. The oligonucleotides of the present invention may also be used for research purposes. Thus, the specific hybridization exhibited by the oligonucleotides of the present invention may be used for assays, purifications, cellular product preparations and in other methodologies which may be appreciated by persons of ordinary skill in the art.

The present invention employs oligonucleotides for use in antisense modulation of the function of DNA or messenger RNA (mRNA) encoding a protein the modulation of which is desired, and ultimately to regulate the amount of such a protein. Hybridization of an antisense oligonucleotide with its mRNA target interferes with the normal role of mRNA and causes a modulation of its function in cells. The functions of mRNA to be interfered with include all vital functions such as translocation of the RNA to the site for protein translation, actual translation of protein from the RNA, splicing of the RNA to yield one or more mRNA species, and possibly even independent catalytic activity which may be engaged in by the RNA. The overall effect of such

interference with mRNA function is modulation of the expression of a protein, wherein "modulation" means either an increase (stimulation) or a decrease (inhibition) in the expression of the protein. In the context of the present invention, inhibition is the preferred form of modulation of gene expression.

It is preferred to target specific genes for antisense attack. "Targeting" an oligonucleotide to the associated nucleic acid, in the context of this invention, is a multistep process. The process usually begins with the identification of a nucleic acid sequence whose function is to be modulated. This may be, for example, a cellular gene (or mRNA transcribed from the gene) whose expression is associated with a particular disorder or disease state, or a foreign nucleic acid from an infectious agent. In the present invention, the target is a cellular gene associated with hyperproliferative disorders. The targeting process also includes determination of a site or sites within this gene for the oligonucleotide interaction to occur such that the desired effect, either detection or modulation of expression of the protein, will result. Once the target site or sites have been identified, oligonucleotides are chosen which are sufficiently complementary to the target, *i.e.*, hybridize sufficiently well and with sufficient specificity to give the desired effect. Generally, there are five regions of a gene that may be targeted for antisense modulation: the 5' untranslated region (hereinafter, the "5'-UTR"), the translation initiation codon region (hereinafter, the "tIR"), the open reading frame (hereinafter, the "ORF"), the translation termination codon region (hereinafter, the "tTR") and the 3' untranslated region (hereinafter, the "3'-UTR"). As is known in the art, these regions are arranged in a typical messenger RNA molecule in the following order (left to right, 5' to 3'): 5'-UTR, tIR, ORF, tTR, 3'-UTR. As is known in the art, although some eukaryotic transcripts are directly translated, many ORFs

contain one or more sequences, known as "introns," which are excised from a transcript before it is translated; the expressed (unexcised) portions of the ORF are referred to as "exons" (Alberts *et al.*, *Molecular Biology of the Cell*, **1983**, Garland Publishing Inc., New York, pp. 411-415). Furthermore, because many eukaryotic ORFs are a thousand nucleotides or more in length, it is often convenient to subdivide the ORF into, e.g., the 5' ORF region, the central ORF region, and the 3' ORF region. In some instances, an ORF contains one or more sites that may be targeted due to some functional significance *in vivo*. Examples of the latter types of sites include intragenic stem-loop structures (see, e.g., U.S. Patent No. 5,512,438) and, in unprocessed mRNA molecules, intron/exon splice sites.

Within the context of the present invention, one preferred intragenic site is the region encompassing the translation initiation codon of the open reading frame (ORF) of the gene. Because, as is known in the art, the translation initiation codon is typically 5'-AUG (in transcribed mRNA molecules; 5'-ATG in the corresponding DNA molecule), the translation initiation codon is also referred to as the "AUG codon," the "start codon" or the "AUG start codon." A minority of genes have a translation initiation codon having the RNA sequence 5'-GUG, 5'-UUG or 5'-CUG, and 5'-AUA, 5'-ACG and 5'-CUG have been shown to function *in vivo*. Furthermore, 5'-UUU functions as a translation initiation codon *in vitro* (Brigstock *et al.*, *Growth Factors*, **1990**, *4*, 45; Gelbert *et al.*, *Somat. Cell. Mol. Genet.*, **1990**, *16*, 173; Gold and Stormo, in: *Escherichia coli and Salmonella typhimurium: Cellular and Molecular Biology*, Vol. 2, **1987**, Neidhardt *et al.*, Eds., American Society for Microbiology, Washington, D.C., p. 1303). Thus, the terms "translation initiation codon" and "start codon" can encompass many codon sequences, even though the initiator amino acid in each instance is typically methionine

(in eukaryotes) or formylmethionine (prokaryotes). It is also known in the art that eukaryotic and prokaryotic genes may have two or more alternative start codons, any one of which may be preferentially utilized for translation initiation in a particular cell type or tissue, or under a particular set of conditions, in order to generate related polypeptides having different amino terminal sequences (Markussen *et al.*, *Development*, **1995**, *121*, 3723; Gao *et al.*, *Cancer Res.*, **1995**, *55*, 743; McDermott *et al.*, *Gene*, **1992**, *117*, 193; Perri *et al.*, *J. Biol. Chem.*, **1991**, *266*, 12536; French *et al.*, *J. Virol.*, **1989**, *63*, 3270; Pushpa-Rekha *et al.*, *J. Biol. Chem.*, **1995**, *270*, 26993; Monaco *et al.*, *J. Biol. Chem.*, **1994**, *269*, 347; DeVirgilio *et al.*, *Yeast*, 1992, *8*, 1043; Kanagasundaram *et al.*, *Biochim. Biophys. Acta*, **1992**, *1171*, 198; Olsen *et al.*, *Mol. Endocrinol.*, **1991**, *5*, 1246; Saul *et al.*, *Appl. Environ. Microbiol.*, **1990**, *56*, 3117; Yaoita *et al.*, *Proc. Natl. Acad. Sci. USA*, **1990**, *87*, 7090; Rogers *et al.*, *EMBO J.*, **1990**, *9*, 2273). In the context of the invention, "start codon" and "translation initiation codon" refer to the codon or codons that are used *in vivo* to initiate translation of an mRNA molecule transcribed from a gene encoding a JNK protein, regardless of the sequence(s) of such codons. It is also known in the art that a translation termination codon (or "stop codon") of a gene may have one of three sequences, i.e., 5'-UAA, 5'-UAG and 5'-UGA (the corresponding DNA sequences are 5'-TAA, 5'-TAG and 5'-TGA, respectively). The terms "start codon region" and "translation initiation region" refer to a portion of such an mRNA or gene that encompasses from about 25 to about 50 contiguous nucleotides in either direction (*i.e.*, 5' or 3') from a translation initiation codon. Similarly, the terms "stop codon region" and "translation termination region" refer to a portion of such an mRNA or gene that encompasses from about 25 to about 50 contiguous

nucleotides in either direction (*i.e.*, 5' or 3') from a translation termination codon.

The remainder of the Detailed Description relates in more detail the (**1**) Oligonucleotides of the Invention and their (**2**) Bioequivalents, (**3**) Utility, (**4**) Pharmaceutical Compositions and (**5**) Means of Administration.

1. Oligonucleotides of the Invention: The present invention employs oligonucleotides for use in antisense modulation of one or more JNK proteins. In the context of this invention, the term "oligonucleotide" refers to an oligomer or polymer of ribonucleic acid or deoxyribonucleic acid. This term includes oligonucleotides composed of naturally-occurring nucleobases, sugars and covalent intersugar (backbone) linkages as well as oligonucleotides having non-naturally-occurring portions which function similarly. Such modified or substituted oligonucleotides are often preferred over native forms because of desirable properties such as, for example, enhanced cellular uptake, enhanced binding to target and increased stability in the presence of nucleases.

An oligonucleotide is a polymer of a repeating unit generically known as a nucleotide. The oligonucleotides in accordance with this invention preferably comprise from about 8 to about 30 nucleotides. An unmodified (naturally occurring) nucleotide has three components: (1) a nitrogen-containing heterocyclic *base* linked by one of its nitrogen atoms to (2) a 5-pentofuranosyl *sugar* and (3) a *phosphate* esterified to one of the 5' or 3' carbon atoms of the sugar. When incorporated into an oligonucleotide chain, the phosphate of a first nucleotide is also esterified to an adjacent sugar of a second, adjacent nucleotide via a 3'-5' phosphate linkage. The "backbone" of an unmodified oligonucleotide consists of (2) and (3), that is, sugars linked together by phosphodiester linkages between the 5' carbon of the sugar of

a first nucleotide and the 3' carbon of a second, adjacent nucleotide. A "nucleoside" is the combination of (1) a nucleobase and (2) a sugar in the absence of (3) a phosphate moiety (Kornberg, A., *DNA Replication*, W.H. Freeman & Co., San Francisco, **1980**, pages 4-7). The backbone of an oligonucleotide positions a series of bases in a specific order; the written representation of this series of bases, which is conventionally written in 5' to 3' order, is known as a nucleotide sequence.

Oligonucleotides may comprise nucleotide sequences sufficient in identity and number to effect specific hybridization with a particular nucleic acid. Such oligonucleotides which specifically hybridize to a portion of the sense strand of a gene are commonly described as "antisense." In the context of the invention, "hybridization" means hydrogen bonding, which may be Watson-Crick, Hoogsteen or reversed Hoogsteen hydrogen bonding, between complementary nucleotides. For example, adenine and thymine are complementary nucleobases which pair through the formation of hydrogen bonds. "Complementary," as used herein, refers to the capacity for precise pairing between two nucleotides. For example, if a nucleotide at a certain position of an oligonucleotide is capable of hydrogen bonding with a nucleotide at the same position of a DNA or RNA molecule, then the oligonucleotide and the DNA or RNA are considered to be complementary to each other at that position. The oligonucleotide and the DNA or RNA are complementary to each other when a sufficient number of corresponding positions in each molecule are occupied by nucleotides which can hydrogen bond with each other. Thus, "specifically hybridizable" and "complementary" are terms which are used to indicate a sufficient degree of complementarity or precise pairing such that stable and specific binding occurs between the oligonucleotide and the DNA or RNA target. An oligonucleotide is specifically hybridizable to its target sequence due to the

formation of base pairs between specific partner nucleobases in the interior of a nucleic acid duplex. Among the naturally occurring nucleobases, guanine (G) binds to cytosine (C), and adenine (A) binds to thymine (T) or uracil (U). In addition to the equivalency of U (RNA) and T (DNA) as partners for A, other naturally occurring nucleobase equivalents are known, including 5-methylcytosine, 5-hydroxymethylcytosine (HMC), glycosyl HMC and gentiobiosyl HMC (C equivalents), and 5-hydroxymethyluracil (U equivalent). Furthermore, synthetic nucleobases which retain partner specificity are known in the art and include, for example, 7-deaza-Guanine, which retains partner specificity for C. Thus, an oligonucleotide's capacity to specifically hybridize with its target sequence will not be altered by any chemical modification to a nucleobase in the nucleotide sequence of the oligonucleotide which does not significantly effect its specificity for the partner nucleobase in the target oligonucleotide. It is understood in the art that an oligonucleotide need not be 100% complementary to its target DNA sequence to be specifically hybridizable. An oligonucleotide is specifically hybridizable when there is a sufficient degree of complementarity to avoid non-specific binding of the oligonucleotide to non-target sequences under conditions in which specific binding is desired, *i.e.*, under physiological conditions in the case of *in vivo* assays or therapeutic treatment, and in the case of *in vitro* assays, under conditions in which the assays are performed.

Antisense oligonucleotides are commonly used as research reagents, diagnostic aids, and therapeutic agents. For example, antisense oligonucleotides, which are able to inhibit gene expression with exquisite specificity, are often used by those of ordinary skill to elucidate the function of particular genes, for example to distinguish between the functions of various members of a biological pathway. This specific inhibitory effect has, therefore, been harnessed by

those skilled in the art for research uses. The specificity and sensitivity of oligonucleotides is also harnessed by those of skill in the art for therapeutic uses.

A. Modified Linkages: Specific examples of some preferred modified oligonucleotides envisioned for this invention include those containing phosphorothioates, phosphotriesters, methyl phosphonates, short chain alkyl or cycloalkyl intersugar linkages or short chain heteroatomic or heterocyclic intersugar linkages. Most preferred are oligonucleotides with phosphorothioates and those with CH_2-NH-O-CH_2, CH_2-N(CH_3)-O-CH_2 [known as a methylene(methylimino) or MMI backbone], CH_2-O-N(CH_3)-CH_2, CH_2-N(CH_3)-N(CH_3)-CH_2 and O-N(CH_3)-CH_2-CH_2 backbones, wherein the native phosphodiester backbone is represented as O-P-O-CH_2). Also preferred are oligonucleotides having morpholino backbone structures (Summerton and Weller, U.S. Patent No. 5,034,506). Further preferred are oligonucleotides with NR-C(*)-CH_2-CH_2, CH_2-NR-C(*)-CH_2, CH_2-CH_2-NR-C(*), C(*)-NR-CH_2-CH_2 and CH_2-C(*)-NR-CH_2 backbones, wherein "*" represents O or S (known as amide backbones; DeMesmaeker *et al.*, WO 92/20823, published November 26, 1992). In other preferred embodiments, such as the peptide nucleic acid (PNA) backbone, the phosphodiester backbone of the oligonucleotide is replaced with a polyamide backbone, the nucleobases being bound directly or indirectly to the aza nitrogen atoms of the polyamide backbone (Nielsen *et al.*, *Science*, **1991**, *254*, 1497; U.S. Patent No. 5,539,082).

B. Modified Nucleobases: The oligonucleotides of the invention may additionally or alternatively include nucleobase modifications or substitutions. As used herein, "unmodified" or "natural" nucleobases include adenine (A), guanine (G), thymine (T), cytosine (C) and uracil (U). Modified nucleobases include nucleobases found only infrequently or transiently in natural nucleic acids, *e.g.*, hypoxanthine, 6-methyladenine, 5-methylcytosine, 5-

hydroxymethylcytosine (HMC), glycosyl HMC and gentiobiosyl HMC, as well synthetic nucleobases, *e.g.*, 2-aminoadenine, 2-thiouracil, 2-thiothymine, 5-bromouracil, 5-hydroxymethyluracil, 8-azaguanine, 7-deazaguanine, N^6(6-aminohexyl)adenine and 2,6-diaminopurine (Kornberg, A., *DNA Replication*, W.H. Freeman & Co., San Francisco, **1980**, pages 75-77; Gebeyehu, G., *et al.*, *Nucleic Acids Res.*, **1987**, *15*, 4513).

C. Sugar Modifications: Modified oligonucleotides may also contain one or more substituted sugar moieties. Preferred oligonucleotides comprise one of the following at the 2' position: OH; F; O-, S-, or N-alkyl; O-, S-, or N-alkenyl; O-, S- or N-alkynyl; or O-alkyl-O-alkyl, wherein the alkyl, alkenyl and alkynyl may be substituted or unsubstituted C_1 to C_{10} alkyl or C_2 to C_{10} alkenyl and alkynyl. Particularly preferred are $O[(CH_2)_nO]_mCH_3$, $O(CH_2)_nOCH_3$, $O(CH_2)_nNH_2$, $O(CH_2)_nCH_3$, $O(CH_2)_nONH_2$, and $O(CH_2)_nON[(CH_2)_nCH_3)]_2$, where n and m are from 1 to about 10. Other preferred oligonucleotides comprise one of the following at the 2' position: C_1 to C_{10} lower alkyl, substituted lower alkyl, alkaryl, aralkyl, O-alkaryl or O-aralkyl, SH, SCH_3, OCN, Cl, Br, CN, CF_3, OCF_3, $SOCH_3$, SO_2CH_3, ONO_2, NO_2, N_3, NH_2, heterocycloalkyl, heterocycloalkaryl, aminoalkylamino, polyalkylamino, substituted silyl, an RNA cleaving group, a reporter group, an intercalator, a group for improving the pharmacokinetic properties of an oligonucleotide, or a group for improving the pharmacodynamic properties of an oligonucleotide, and other substituents having similar properties. A preferred modification includes an alkoxyalkoxy group, 2'-methoxyethoxy (2'-O-$CH_2CH_2OCH_3$, also known as 2'-O-(2-methoxyethyl) or 2'-MOE) (Martin et al., *Helv. Chim. Acta*, **1995**, *78*, 486-504). Further preferred modifications include 2'-dimethylaminooxyethoxy, i.e., a 2'-$O(CH_2)_2ON(CH_3)_2$ group, also known as 2'-DMAOE and 2'-dimethylaminoethoxyethoxy, i.e., 2'-O-CH_2-O-CH_2-$N(CH_2)_2$.

Other preferred modifications include 2'-methoxy (2'-O-CH_3), 2'-aminopropoxy (2'-$OCH_2CH_2CH_2NH_2$) and 2'-fluoro (2'-F). Similar modifications may also be made at other positions on the oligonucleotide, particularly the 3' position of the sugar on the 3' terminal nucleotide or in 2'-5' linked oligonucleotides and the 5' position of 5' terminal nucleotide. Oligonucleotides may also have sugar mimetics such as cyclobutyl moieties in place of the pentofuranosyl sugar. Representative United States patents that teach the preparation of such modified sugar structures include, but are not limited to, U.S. Patent No. 4,981,957; 5,118,800; 5,319,080; 5,359,044; 5,393,878; 5,446,137; 5,466,786; 5,514,785; 5,519,134; 5,567,811; 5,576,427; 5,591,722; 5,597,909; 5,610,300; 5,627,053; 5,639,873; 5,646,265; 5,658,873; 5,670,633; and 5,700,920, each of which is herein incorporated by reference.

D. Other Modifications: Similar modifications may also be made at other positions on the oligonucleotide, particularly the 3' position of the sugar on the 3' terminal nucleotide and the 5' position of 5' terminal nucleotide. The 5' and 3' termini of an oligonucleotide may also be modified to serve as points of chemical conjugation of, *e.g.*, lipophilic moieties (see immediately subsequent paragraph), intercalating agents (Kuyavin *et al.*, WO 96/32496, published October 17, **1996**; Nguyen *et al.*, U.S. Patent No. 4,835,263, issued May 30, 1989) or hydroxyalkyl groups (Helene *et al.*, WO 96/34008, published October 31, **1996**).

Other positions within an oligonucleotide of the invention can be used to chemically link thereto one or more effector groups to form an oligonucleotide conjugate. An "effector group" is a chemical moiety that is capable of carrying out a particular chemical or biological function. Examples of such effector groups include, but are not limited to, an RNA cleaving group, a reporter group, an intercalator,

a group for improving the pharmacokinetic properties of an oligonucleotide, or a group for improving the pharmacodynamic properties of an oligonucleotide and other substituents having similar properties. A variety of chemical linkers may be used to conjugate an effector group to an oligonucleotide of the invention. As an example, U.S. Patent No. 5,578,718 to Cook *et al.* discloses methods of attaching an alkylthio linker, which may be further derivatized to include additional groups, to ribofuranosyl positions, nucleosidic base positions, or on internucleoside linkages. Additional methods of conjugating oligonucleotides to various effector groups are known in the art; see, *e.g.*, *Protocols for Oligonucleotide Conjugates (Methods in Molecular Biology, Volume 26)* Agrawal, S., ed., Humana Press, Totowa, NJ, **1994**.

Another preferred additional or alternative modification of the oligonucleotides of the invention involves chemically linking to the oligonucleotide one or more lipophilic moieties which enhance the cellular uptake of the oligonucleotide. Such lipophilic moieties may be linked to an oligonucleotide at several different positions on the oligonucleotide. Some preferred positions include the 3' position of the sugar of the 3' terminal nucleotide, the 5' position of the sugar of the 5' terminal nucleotide, and the 2' position of the sugar of any nucleotide. The N^6 position of a purine nucleobase may also be utilized to link a lipophilic moiety to an oligonucleotide of the invention (Gebeyehu, G., *et al.*, *Nucleic Acids Res.*, **1987**, *15*, 4513). Such lipophilic moieties include but are not limited to a cholesteryl moiety (Letsinger *et al.*, *Proc. Natl. Acad. Sci. U.S.A.*, **1989**, *86*, 6553), cholic acid (Manoharan *et al.*, *Bioorg. Med. Chem. Let.*, **1994**, *4*, 1053), a thioether, *e.g.*, hexyl-*S*-tritylthiol (Manoharan *et al.*, *Ann. N.Y. Acad. Sci.*, **1992**, *660*, 306; Manoharan *et al.*, *Bioorg. Med. Chem. Let.*, **1993**, *3*, 2765), a thiocholesterol (Oberhauser *et al.*, *Nucl. Acids Res.*, **1992**, *20*, 533), an

aliphatic chain, *e.g.*, dodecandiol or undecyl residues (Saison-Behmoaras *et al.*, *EMBO J.*, **1991**, *10*, 111; Kabanov *et al.*, *FEBS Lett.*, **1990**, *259*, 327; Svinarchuk *et al.*, *Biochimie*, **1993**, *75*, 49), a phospholipid, *e.g.*, di-hexadecyl-*rac*-glycerol or triethylammonium 1,2-di-O-hexadecyl-*rac*-glycero-3-H-phosphonate (Manoharan *et al.*, *Tetrahedron Lett.*, **1995**, *36*, 3651; Shea *et al.*, *Nucl. Acids Res.*, **1990**, *18*, 3777), a polyamine or a polyethylene glycol chain (Manoharan *et al.*, *Nucleosides & Nucleotides*, **1995**, *14*, 969), or adamantane acetic acid (Manoharan *et al.*, *Tetrahedron Lett.*, **1995**, *36*, 3651), a palmityl moiety (Mishra *et al.*, *Biochim. Biophys. Acta*, **1995**, *1264*, 229), or an octadecylamine or hexylamino-carbonyl-oxycholesterol moiety (Crooke *et al.*, *J. Pharmacol. Exp. Ther.*, **1996**, *277*, 923). Oligonucleotides comprising lipophilic moieties, and methods for preparing such oligonucleotides, are disclosed in U.S. Patents No. 5,138,045, 5,218,105 and 5,459,255.

The present invention also includes oligonucleotides that are substantially chirally pure with regard to particular positions within the oligonucleotides. Examples of substantially chirally pure oligonucleotides include, but are not limited to, those having phosphorothioate linkages that are at least 75% Sp or Rp (Cook *et al.*, U.S. Patent No. 5,587,361) and those having substantially chirally pure (Sp or Rp) alkylphosphonate, phosphoamidate or phosphotriester linkages (Cook, U.S. Patent No. 5,212,295 and 5,521,302).

E. Chimeric Oligonucleotides: The present invention also includes oligonucleotides which are chimeric oligonucleotides. "Chimeric" oligonucleotides or "chimeras," in the context of this invention, are oligonucleotides which contain two or more chemically distinct regions, each made up of at least one nucleotide. These oligonucleotides typically contain at least one region wherein the oligonucleotide is modified so as to confer upon the oligonucleotide increased

resistance to nuclease degradation, increased cellular uptake, and/or increased binding affinity for the target nucleic acid. An additional region of the oligonucleotide may serve as a substrate for enzymes capable of cleaving RNA:DNA or RNA:RNA hybrids. By way of example, RNase H is a cellular endonuclease which cleaves the RNA strand of an RNA:DNA duplex. Activation of RNase H, therefore, results in cleavage of the RNA target, thereby greatly enhancing the efficiency of antisense inhibition of gene expression. Cleavage of the RNA target can be routinely detected by gel electrophoresis and, if necessary, associated nucleic acid hybridization techniques known in the art. By way of example, such "chimeras" may be "gapmers," *i.e.*, oligonucleotides in which a central portion (the "gap") of the oligonucleotide serves as a substrate for, e.g., RNase H, and the 5' and 3' portions (the "wings") are modified in such a fashion so as to have greater affinity for the target RNA molecule but are unable to support nuclease activity (*e.g.*, 2'-fluoro- or 2'-methoxyethoxy- substituted). Other chimeras include "wingmers," that is, oligonucleotides in which the 5' portion of the oligonucleotide serves as a substrate for, *e.g.*, RNase H, whereas the 3' portion is modified in such a fashion so as to have greater affinity for the target RNA molecule but is unable to support nuclease activity (*e.g.*, 2'-fluoro- or 2'-methoxyethoxy- substituted), or *vice-versa*.

F. Synthesis: The oligonucleotides used in accordance with this invention may be conveniently and routinely made through the well-known technique of solid phase synthesis. Equipment for such synthesis is sold by several vendors including, for example, Applied Biosystems (Foster City, CA). Any other means for such synthesis known in the art may additionally or alternatively be employed. It is also known to use similar techniques to prepare other oligonucleotides such as the phosphorothioates and alkylated derivatives.

1. **Teachings** regarding the synthesis of particular modified oligonucleotides may be found in the following U.S. patents or pending patent applications, each of which is commonly assigned with this application: U.S. Patent No. 5,138,045 and 5,218,105, drawn to polyamine conjugated oligonucleotides; U.S. Patent No. 5,212,295, drawn to monomers for the preparation of oligonucleotides having chiral phosphorus linkages; U.S. Patent No. 5,378,825 and 5,541,307, drawn to oligonucleotides having modified backbones; U.S. Patent No. 5,386,023, drawn to backbone modified oligonucleotides and the preparation thereof through reductive coupling; U.S. Patent No. 5,457,191, drawn to modified nucleobases based on the 3-deazapurine ring system and methods of synthesis thereof; U.S. Patent No. 5,459,255, drawn to modified nucleobases based on N-2 substituted purines; U.S. Patent No. 5,521,302, drawn to processes for preparing oligonucleotides having chiral phosphorus linkages; U.S. Patent No. 5,539,082, drawn to peptide nucleic acids; U.S. Patent No. 5,554,746, drawn to oligonucleotides having ß-lactam backbones; U.S. Patent No. 5,571,902, drawn to methods and materials for the synthesis of oligonucleotides; U.S. Patent No. 5,578,718, drawn to nucleosides having alkylthio groups, wherein such groups may be used as linkers to other moieties attached at any of a variety of positions of the nucleoside; U.S. Patent No. 5,587,361 and 5,599,797, drawn to oligonucleotides having phosphorothioate linkages of high chiral purity; U.S. Patent No. 5,506,351, drawn to processes for the preparation of 2'-O-alkyl guanosine and related compounds, including 2,6-diaminopurine compounds; U.S. Patent No. 5,587,469, drawn to oligonucleotides having N-2 substituted purines; U.S. Patent No. 5,587,470, drawn to oligonucleotides having 3-deazapurines; U.S. Patent No. 5,223,168, issued June 29, 1993, and 5,608,046, both drawn to conjugated 4'-desmethyl nucleoside analogs; U.S. Patent No. 5,602,240, and 5,610,289, drawn to backbone modified

oligonucleotide analogs; and U. S. Patent Application Serial No. 08/383,666, filed February 3, 1995, and U.S. Patent No. 5,459,255, drawn to, *inter alia*, methods of synthesizing 2'-fluoro-oligonucleotides.

2. 5-methyl-cytosine: In 2'-methoxyethoxy-modified oligonucleotides, 5-methyl-2'-methoxyethoxy-cytosine residues are used and are prepared as follows.

(a) 2,2'-Anhydro[1-(ß-D-arabinofuranosyl)-5-methyluridine]: 5-Methyluridine (ribosylthymine, commercially available through Yamasa, Choshi, Japan) (72.0 g, 0.279 M), diphenylcarbonate (90.0 g, 0.420 M) and sodium bicarbonate (2.0 g, 0.024 M) were added to DMF (300 mL). The mixture was heated to reflux, with stirring, allowing the evolved carbon dioxide gas to be released in a controlled manner. After 1 hour, the slightly darkened solution was concentrated under reduced pressure. The resulting syrup was poured into diethylether (2.5 L), with stirring. The product formed a gum. The ether was decanted and the residue was dissolved in a minimum amount of methanol (ca. 400 mL). The solution was poured into fresh ether (2.5 L) to yield a stiff gum. The ether was decanted and the gum was dried in a vacuum oven (60?C at 1 mm Hg for 24 h) to give a solid which was crushed to a light tan powder (57 g, 85% crude yield). The material was used as is for further reactions.

(b) 2'-O-Methoxyethyl-5-methyluridine: 2,2'-Anhydro-5-methyluridine (195 g, 0.81 M), tris(2-methoxyethyl)borate (231 g, 0.98 M) and 2-methoxyethanol (1.2 L) were added to a 2 L stainless steel pressure vessel and placed in a pre-heated oil bath at 160?C. After heating for 48 hours at 155-160?C, the vessel was opened and the solution evaporated to dryness and triturated with MeOH (200 mL). The residue was suspended in hot acetone (1 L). The insoluble salts were filtered, washed with acetone (150 mL) and the

filtrate evaporated. The residue (280 g) was dissolved in CH_3CN (600 mL) and evaporated. A silica gel column (3 kg) was packed in CH_2Cl_2/acetone/MeOH (20:5:3) containing 0.5% Et_3NH. The residue was dissolved in CH_2Cl_2 (250 mL) and adsorbed onto silica (150 g) prior to loading onto the column. The product was eluted with the packing solvent to give 160 g (63%) of product.

(c) 2'-O-Methoxyethyl-5'-O-dimethoxytrityl-5-methyluridine: 2'-O-Methoxyethyl-5-methyluridine (160 g, 0.506 M) was co-evaporated with pyridine (250 mL) and the dried residue dissolved in pyridine (1.3 L). A first aliquot of dimethoxytrityl chloride (94.3 g, 0.278 M) was added and the mixture stirred at room temperature for one hour. A second aliquot of dimethoxytrityl chloride (94.3 g, 0.278 M) was added and the reaction stirred for an additional one hour. Methanol (170 mL) was then added to stop the reaction. HPLC showed the presence of approximately 70% product. The solvent was evaporated and triturated with CH_3CN (200 mL). The residue was dissolved in $CHCl_3$ (1.5 L) and extracted with 2x 500 mL of saturated $NaHCO_3$ and 2x 500 mL of saturated NaCl. The organic phase was dried over Na_2SO_4, filtered and evaporated. 275 g of residue was obtained. The residue was purified on a 3.5 kg silica gel column, packed and eluted with EtOAc/Hexane/Acetone (5:5:1) containing 0.5% Et_3NH. The pure fractions were evaporated to give 164 g of product. Approximately 20 g additional was obtained from the impure fractions to give a total yield of 183 g (57%).

(d) 3'-O-Acetyl-2'-O-methoxyethyl-5'-O-dimethoxytrityl-5-methyluridine: 2'-O-Methoxyethyl-5'-O-dimethoxytrityl-5-methyluridine (106 g, 0.167 M), DMF/pyridine (750 mL of a 3:1 mixture prepared from 562 mL of DMF and 188 mL of pyridine) and acetic anhydride (24.38 mL, 0.258 M) were combined and stirred at room temperature for 24 hours. The reaction was monitored by tlc by first quenching the tlc

sample with the addition of MeOH. Upon completion of the reaction, as judged by tlc, MeOH (50 mL) was added and the mixture evaporated at 35?C. The residue was dissolved in $CHCl_3$ (800 mL) and extracted with 2x 200 mL of saturated sodium bicarbonate and 2x 200 mL of saturated NaCl. The water layers were back extracted with 200 mL of $CHCl_3$. The combined organics were dried with sodium sulfate and evaporated to give 122 g of residue (approximately 90% product). The residue was purified on a 3.5 kg silica gel column and eluted using EtOAc/Hexane (4:1). Pure product fractions were evaporated to yield 96 g (84%).

(e) 3'-O-Acetyl-2'-O-methoxyethyl-5'-O-dimethoxytrityl-5-methyl-4-triazoleuridine: A first solution was prepared by dissolving 3'-O-acetyl-2'-O-methoxyethyl-5'-O-dimethoxytrityl-5-methyluridine (96 g, 0.144 M) in CH_3CN (700 mL) and set aside. Triethylamine (189 mL, 1.44 M) was added to a solution of triazole (90 g, 1.3 M) in CH_3CN (1 L), cooled to -5?C and stirred for 0.5 h using an overhead stirrer. $POCl_3$ was added dropwise, over a 30 minute period, to the stirred solution maintained at 0-10?C, and the resulting mixture stirred for an additional 2 hours. The first solution was added dropwise, over a 45 minute period, to the later solution. The resulting reaction mixture was stored overnight in a cold room. Salts were filtered from the reaction mixture and the solution was evaporated. The residue was dissolved in EtOAc (1 L) and the insoluble solids were removed by filtration. The filtrate was washed with 1x 300 mL of $NaHCO_3$ and 2x 300 mL of saturated NaCl, dried over sodium sulfate and evaporated. The residue was triturated with EtOAc to give the title compound.

(f) 2'-O-Methoxyethyl-5'-O-dimethoxytrityl-5-methylcytidine: A solution of 3'-O-acetyl-2'-O-methoxyethyl-5'-O-dimethoxytrityl-5-methyl-4-triazoleuridine (103 g, 0.141 M) in dioxane (500 mL) and NH_4OH

(30 mL) was stirred at room temperature for 2 hours. The dioxane solution was evaporated and the residue azeotroped with MeOH (2x 200 mL). The residue was dissolved in MeOH (300 mL) and transferred to a 2 liter stainless steel pressure vessel. Methanol (400 mL) saturated with NH_3 gas was added and the vessel heated to 100?C for 2 hours (thin layer chromatography, tlc, showed complete conversion). The vessel contents were evaporated to dryness and the residue was dissolved in EtOAc (500 mL) and washed once with saturated NaCl (200 mL). The organics were dried over sodium sulfate and the solvent was evaporated to give 85 g (95%) of the title compound.

(g) N^4-Benzoyl-2'-O-methoxyethyl-5'-O-dimethoxytrityl-5-methylcytidine: 2'-O-Methoxyethyl-5'-O-dimethoxytrityl-5-methylcytidine (85 g, 0.134 M) was dissolved in DMF (800 mL) and benzoic anhydride (37.2 g, 0.165 M) was added with stirring. After stirring for 3 hours, tlc showed the reaction to be approximately 95% complete. The solvent was evaporated and the residue azeotroped with MeOH (200 mL). The residue was dissolved in $CHCl_3$ (700 mL) and extracted with saturated $NaHCO_3$ (2x 300 mL) and saturated NaCl (2x 300 mL), dried over $MgSO_4$ and evaporated to give a residue (96 g). The residue was chromatographed on a 1.5 kg silica column using EtOAc/Hexane (1:1) containing 0.5% Et_3NH as the eluting solvent. The pure product fractions were evaporated to give 90 g (90%) of the title compound.

(h) N^4-Benzoyl-2'-O-methoxyethyl-5'-O-dimethoxytrityl-5-methylcytidine-3'-amidite: N^4-Benzoyl-2'-O-methoxyethyl-5'-O-dimethoxytrityl-5-methylcytidine (74 g, 0.10 M) was dissolved in CH_2Cl_2 (1 L). Tetrazole diisopropylamine (7.1 g) and 2-cyanoethoxy-tetra(isopropyl)phosphite (40.5 mL, 0.123 M) were added with stirring, under a nitrogen atmosphere. The resulting mixture was stirred for 20 hours at room temperature (tlc showed the reaction to be 95%

complete). The reaction mixture was extracted with saturated $NaHCO_3$ (1x 300 mL) and saturated NaCl (3x 300 mL). The aqueous washes were back-extracted with CH_2Cl_2 (300 mL), and the extracts were combined, dried over $MgSO_4$ and concentrated. The residue obtained was chromatographed on a 1.5 kg silica column using EtOAc\Hexane (3:1) as the eluting solvent. The pure fractions were combined to give 90.6 g (87%) of the title compound.

3. 2'-O-(Aminooxyethyl) nucleoside amidites and 2'-O-(dimethylaminooxyethyl) nucleoside amidites

2'-(Dimethylaminooxyethoxy) nucleoside amidites

2'-(Dimethylaminooxyethoxy) nucleoside amidites [also known in the art as 2'-O-(dimethylaminooxyethyl) nucleoside amidites] are prepared as described in the following paragraphs. Adenosine, cytidine and guanosine nucleoside amidites are prepared similarly to the thymidine (5-methyluridine) except the exocyclic amines are protected with a benzoyl moiety in the case of adenosine and cytidine and with isobutyryl in the case of guanosine.

5'-O-tert-Butyldiphenylsilyl-O^2-2'-anhydro-5-methyluridine

O^2-2'-anhydro-5-methyluridine (Pro. Bio. Sint., Varese, Italy, 100.0g, 0.416 mmol), dimethylaminopyridine (0.66g, 0.013eq, 0.0054mmol) were dissolved in dry pyridine (500 ml) at ambient temperature under an argon atmosphere and with mechanical stirring. *tert*-Butyldiphenylchlorosilane (125.8g, 119.0mL, 1.1eq, 0.458mmol) was added in one portion. The reaction was stirred for 16 h at ambient temperature. TLC (Rf 0.22, ethyl acetate) indicated a complete reaction. The solution was concentrated under reduced pressure to a thick oil. This was partitioned between dichloromethane (1 L) and saturated sodium bicarbonate (2x1 L) and brine (1 L). The

organic layer was dried over sodium sulfate and concentrated under reduced pressure to a thick oil. The oil was dissolved in a 1:1 mixture of ethyl acetate and ethyl ether (600mL) and the solution was cooled to -10°C. The resulting crystalline product was collected by filtration, washed with ethyl ether (3x200 mL) and dried (40°C, 1mm Hg, 24 h) to 149g (74.8%) of white solid. TLC and NMR were consistent with pure product.

5'-O-tert-Butyldiphenylsilyl-2'-O-(2-hydroxyethyl)-5-methyluridine

In a 2 L stainless steel, unstirred pressure reactor was added borane in tetrahydrofuran (1.0 M, 2.0 eq, 622 mL). In the fume hood and with manual stirring, ethylene glycol (350 mL, excess) was added cautiously at first until the evolution of hydrogen gas subsided. 5'-O-tert-Butyldiphenylsilyl-O^2-2'-anhydro-5-methyluridine (149 g, 0.311 mol) and sodium bicarbonate (0.074 g, 0.003 eq) were added with manual stirring. The reactor was sealed and heated in an oil bath until an internal temperature of 160 °C was reached and then maintained for 16 h (pressure < 100 psig). The reaction vessel was cooled to ambient and opened. TLC (Rf 0.67 for desired product and Rf 0.82 for ara-T side product, ethyl acetate) indicated about 70% conversion to the product. In order to avoid additional side product formation, the reaction was stopped, concentrated under reduced pressure (10 to 1mm Hg) in a warm water bath (40-100°C) with the more extreme conditions used to remove the ethylene glycol. [Alternatively, once the low boiling solvent is gone, the remaining solution can be partitioned between ethyl acetate and water. The product will be in the organic phase.] The residue was purified by column chromatography (2kg silica gel, ethyl acetate-hexanes gradient 1:1 to 4:1). The appropriate fractions were combined, stripped and dried to product as a white crisp foam (84g, 50%), contaminated starting material (17.4g) and pure reusable starting material 20g. The yield

based on starting material less pure recovered starting material was 58%. TLC and NMR were consistent with 99% pure product.

2'-O-([2-phthalimidoxy)ethyl]-5'-*t*-butyldiphenylsilyl-5-methyluridine

5'-O-tert-Butyldiphenylsilyl-2'-O-(2-hydroxyethyl)-5-methyluridine (20g, 36.98mmol) was mixed with triphenylphosphine (11.63g, 44.36mmol) and N-hydroxyphthalimide (7.24g, 44.36mmol). It was then dried over P_2O_5 under high vacuum for two days at 40?C. The reaction mixture was flushed with argon and dry THF (369.8mL, Aldrich, sure seal bottle) was added to get a clear solution. Diethyl-azodicarboxylate (6.98mL, 44.36mmol) was added dropwise to the reaction mixture. The rate of addition is maintained such that resulting deep red coloration is just discharged before adding the next drop. After the addition was complete, the reaction was stirred for 4 hrs. By that time TLC showed the completion of the reaction (ethylacetate:hexane, 60:40). The solvent was evaporated in vacuum. Residue obtained was placed on a flash column and eluted with ethyl acetate:hexane (60:40), to get 2'-O-([2-phthalimidoxy)ethyl]-5'-*t*-butyldiphenylsilyl-5-methyluridine as white foam (21.819 g, 86%).

5'-O-*tert*-butyldiphenylsilyl-2'-O-[(2-formadoximinooxy)ethyl]-5-methyluridine

2'-O-([2-phthalimidoxy)ethyl]-5'-*t*-butyldiphenylsilyl-5-methyluridine (3.1g, 4.5mmol) was dissolved in dry CH_2Cl_2 (4.5mL) and methylhydrazine (300mL, 4.64mmol) was added dropwise at -10?C to 0?C. After 1 h the mixture was filtered, the filtrate was washed with ice cold CH_2Cl_2 and the combined organic phase was washed with water, brine and dried over anhydrous Na_2SO_4. The solution was concentrated to get 2'-O-

(aminooxyethyl) thymidine, which was then dissolved in MeOH (67.5mL). To this formaldehyde (20% aqueous solution, w/w, 1.1 eq.) was added and the resulting mixture was strirred for 1 h. Solvent was removed under vacuum; residue chromatographed to get 5'-O-*tert*-butyldiphenylsilyl-2'-O-[(2-formadoximinooxy) ethyl]-5-methyluridine as white foam (1.95 g, 78%).

5'-O-*tert*-Butyldiphenylsilyl-2'-O-[N,N-dimethylaminooxyethyl]-5-methyluridine

5'-O-*tert*-butyldiphenylsilyl-2'-O-[(2-formadoximinooxy)ethyl]-5-methyluridine (1.77g, 3.12mmol) was dissolved in a solution of 1M pyridinium p-toluenesulfonate (PPTS) in dry MeOH (30.6mL). Sodium cyanoborohydride (0.39g, 6.13mmol) was added to this solution at 10?C under inert atmosphere. The reaction mixture was stirred for 10 minutes at 10?C. After that the reaction vessel was removed from the ice bath and stirred at room temperature for 2 h, the reaction monitored by TLC (5% MeOH in CH_2Cl_2). Aqueous $NaHCO_3$ solution (5%, 10mL) was added and extracted with ethyl acetate (2x20mL). Ethyl acetate phase was dried over anhydrous Na_2SO_4, evaporated to dryness. Residue was dissolved in a solution of 1M PPTS in MeOH (30.6mL). Formaldehyde (20% w/w, 30mL, 3.37mmol) was added and the reaction mixture was stirred at room temperature for 10 minutes. Reaction mixture cooled to 10?C in an ice bath, sodium cyanoborohydride (0.39g, 6.13mmol) was added and reaction mixture stirred at 10?C for 10 minutes. After 10 minutes, the reaction mixture was removed from the ice bath and stirred at room temperature for 2 hrs. To the reaction mixture 5% $NaHCO_3$ (25mL) solution was added and extracted with ethyl acetate (2x25mL). Ethyl acetate layer was dried over anhydrous Na_2SO_4 and evaporated to dryness . The residue obtained was purified by flash column chromatography and eluted with 5% MeOH in CH_2Cl_2 to get 5'-O-

tert-butyldiphenylsilyl-2'-O-[N,N-dimethylaminooxyethyl]-5-methyluridine as a white foam (14.6g, 80%).

2'-O-(dimethylaminooxyethyl)-5-methyluridine

Triethylamine trihydrofluoride (3.91mL, 24.0mmol) was dissolved in dry THF and triethylamine (1.67mL, 12mmol, dry, kept over KOH). This mixture of triethylamine-2HF was then added to 5'-O-*tert*-butyldiphenylsilyl-2'-O-[N,N-dimethylaminooxyethyl]-5-methyluridine (1.40g, 2.4mmol) and stirred at room temperature for 24 hrs. Reaction was monitored by TLC (5% MeOH in CH_2Cl_2). Solvent was removed under vacuum and the residue placed on a flash column and eluted with 10% MeOH in CH_2Cl_2 to get 2'-O-(dimethylaminooxyethyl)-5-methyluridine (766mg, 92.5%).

5'-O-DMT-2'-O-(dimethylaminooxyethyl)-5-methyluridine

2'-O-(dimethylaminooxyethyl)-5-methyluridine (750mg, 2.17mmol) was dried over P_2O_5 under high vacuum overnight at 40?C. It was then co-evaporated with anhydrous pyridine (20mL). The residue obtained was dissolved in pyridine (11mL) under argon atmosphere. 4-dimethylaminopyridine (26.5mg, 2.60mmol), 4,4'-dimethoxytrityl chloride (880mg, 2.60mmol) was added to the mixture and the reaction mixture was stirred at room temperature until all of the starting material disappeared. Pyridine was removed under vacuum and the residue chromatographed and eluted with 10% MeOH in CH_2Cl_2 (containing a few drops of pyridine) to get 5'-O-DMT-2'-O-(dimethylamino-oxyethyl)-5-methyluridine (1.13g, 80%).

5'-O-DMT-2'-O-(2-N,N-dimethylaminooxyethyl)-5-methyluridine-3'-[(2-cyanoethyl)-N,N-diisopropylphosphoramidite]

5'-O-DMT-2'-O-(dimethylaminooxyethyl)-5-methyluridine (1.08g, 1.67mmol) was co-evaporated with toluene (20mL). To

the residue N,N-diisopropylamine tetrazonide (0.29g, 1.67mmol) was added and dried over P_2O_5 under high vacuum overnight at 40?C. Then the reaction mixture was dissolved in anhydrous acetonitrile (8.4mL) and 2-cyanoethyl-N,N,N^1,N^1-tetraisopropylphosphoramidite (2.12mL, 6.08mmol) was added. The reaction mixture was stirred at ambient temperature for 4 hrs under inert atmosphere. The progress of the reaction was monitored by TLC (hexane:ethyl acetate 1:1). The solvent was evaporated, then the residue was dissolved in ethyl acetate (70mL) and washed with 5% aqueous $NaHCO_3$ (40mL). Ethyl acetate layer was dried over anhydrous Na_2SO_4 and concentrated. Residue obtained was chromatographed (ethyl acetate as eluent) to get 5'-O-DMT-2'-O-(2-N,N-dimethylaminooxyethyl)-5-methyluridine-3'-[(2-cyanoethyl)-N,N-diisopropylphosphoramidite] as a foam (1.04g, 74.9%).

2'-(Aminooxyethoxy) nucleoside amidites

2'-(Aminooxyethoxy) nucleoside amidites [also known in the art as 2'-O-(aminooxyethyl) nucleoside amidites] are prepared as described in the following paragraphs. Adenosine, cytidine and thymidine nucleoside amidites are prepared similarly.

N2-isobutyryl-6-O-diphenylcarbamoyl-2'-O-(2-ethylacetyl)-5'-O-(4,4'-dimethoxytrityl)guanosine-3'-[(2-cyanoethyl)-N,N-diisopropylphosphoramidite]

The 2'-O-aminooxyethyl guanosine analog may be obtained by selective 2'-O-alkylation of diaminopurine riboside. Multigram quantities of diaminopurine riboside may be purchased from Schering AG (Berlin) to provide 2'-O-(2-ethylacetyl) diaminopurine riboside along with a minor amount of the 3'-O-isomer. 2'-O-(2-ethylacetyl) diaminopurine riboside may be resolved and converted to 2'-O-(2-ethylacetyl)guanosine by treatment with adenosine deaminase. (McGee, D. P. C., Cook, P. D., Guinosso, C. J., WO 94/02501

A1 940203.) Standard protection procedures should afford 2'-O-(2-ethylacetyl)-5'-O-(4,4'-dimethoxytrityl)guanosine and 2-N-isobutyryl-6-O-diphenylcarbamoyl-2'-O-(2-ethylacetyl)-5'-O-(4,4'-dimethoxytrityl)guanosine which may be reduced to provide 2-N-isobutyryl-6-O-diphenylcarbamoyl-2'-O-(2-ethylacetyl)-5'-O-(4,4'-dimethoxytrityl)guanosine. As before the hydroxyl group may be displaced by N-hydroxyphthalimide via a Mitsunobu reaction, and the protected nucleoside may phosphitylated as usual to yield 2-N-isobutyryl-6-O-diphenylcarbamoyl-2'-O-(2-ethylacetyl)-5'-O-(4,4'-dimethoxytrityl)guanosine-3'-[(2-cyanoethyl)-N,N-diisopropylphosphoramidite].

2. Bioequivalents: The compounds of the invention encompass any pharmaceutically acceptable salts, esters, or salts of such esters, or any other compound which, upon administration to an animal including a human, is capable of providing (directly or indirectly) the biologically active metabolite or residue thereof. Accordingly, for example, the disclosure is also drawn to "prodrugs" and "pharmaceutically acceptable salts" of the oligonucleotides of the invention, pharmaceutically acceptable salts of such prodrugs, and other bioequivalents.

A. Oligonucleotide Prodrugs: The oligonucleotides of the invention may additionally or alternatively be prepared to be delivered in a "prodrug" form. The term "prodrug" indicates a therapeutic agent that is prepared in an inactive form that is converted to an active form (*i.e.*, drug) within the body or cells thereof by the action of endogenous enzymes or other chemicals and/or conditions. In particular, prodrug versions of the oligonucleotides of the invention are prepared as SATE [(S-acetyl-2-thioethyl) phosphate] derivatives according to the methods disclosed in WO 93/24510 to Gosselin *et al.*, published December 9, 1993.

B. Pharmaceutically Acceptable Salts: The term Apharmaceutically acceptable salts" refers to physiologically and pharmaceutically acceptable salts of the oligonucleotides of the invention: *i.e.*, salts that retain the desired biological activity of the parent compound and do not impart undesired toxicological effects thereto.

Pharmaceutically acceptable base addition salts are formed with metals or amines, such as alkali and alkaline earth metals or organic amines. Examples of metals used as cations are sodium, potassium, magnesium, calcium, and the like. Examples of suitable amines are N,N'-dibenzylethylenediamine, chloroprocaine, choline, diethanolamine, dicyclohexylamine, ethylenediamine, N-methylglucamine, and procaine (see, for example, Berge *et al.*, "Pharmaceutical Salts," *J. of Pharma Sci.*, **1977**, *66*, 1). The base addition salts of said acidic compounds are prepared by contacting the free acid form with a sufficient amount of the desired base to produce the salt in the conventional manner. The free acid form may be regenerated by contacting the salt form with an acid and isolating the free acid in the conventional manner. The free acid forms differ from their respective salt forms somewhat in certain physical properties such as solubility in polar solvents, but otherwise the salts are equivalent to their respective free acid for purposes of the present invention. As used herein, a "pharmaceutical addition salt" includes a pharmaceutically acceptable salt of an acid form of one of the components of the compositions of the invention. These include organic or inorganic acid salts of the amines. Preferred acid salts are the hydrochlorides, acetates, salicylates, nitrates and phosphates. Other suitable pharmaceutically acceptable salts are well known to those skilled in the art and include basic salts of a variety of inorganic and organic acids, such as, for example, with inorganic acids, such as for example hydrochloric acid, hydrobromic acid, sulfuric acid or phosphoric acid; with

organic carboxylic, sulfonic, sulfo or phospho acids or N-substituted sulfamic acids, for example acetic acid, propionic acid, glycolic acid, succinic acid, maleic acid, hydroxymaleic acid, methylmaleic acid, fumaric acid, malic acid, tartaric acid, lactic acid, oxalic acid, gluconic acid, glucaric acid, glucuronic acid, citric acid, benzoic acid, cinnamic acid, mandelic acid, salicylic acid, 4-aminosalicylic acid, 2-phenoxybenzoic acid, 2-acetoxybenzoic acid, embonic acid, nicotinic acid or isonicotinic acid; and with amino acids, such as the 20 alpha-amino acids involved in the synthesis of proteins in nature, for example glutamic acid or aspartic acid, and also with phenylacetic acid, methanesulfonic acid, ethanesulfonic acid, 2-hydroxyethanesulfonic acid, ethane-1,2-disulfonic acid, benzenesulfonic acid, 4-methylbenzenesulonic acid, naphthalene-2-sulfonic acid, naphthalene-1,5-disulfonic acid, 2- or 3-phosphoglycerate, glucose-6-phosphate, N-cyclohexylsulfamic acid (with the formation of cyclamates), or with other acid organic compounds, such as ascorbic acid. Pharmaceutically acceptable salts of compounds may also be prepared with a pharmaceutically acceptable cation. Suitable pharmaceutically acceptable cations are well known to those skilled in the art and include alkaline, alkaline earth, ammonium and quaternary ammonium cations. Carbonates or hydrogen carbonates are also possible.

For oligonucleotides, preferred examples of pharmaceutically acceptable salts include but are not limited to (a) salts formed with cations such as sodium, potassium, ammonium, magnesium, calcium, polyamines such as spermine and spermidine, *etc.*; (b) acid addition salts formed with inorganic acids, for example hydrochloric acid, hydrobromic acid, sulfuric acid, phosphoric acid, nitric acid and the like; (c) salts formed with organic acids such as, for example, acetic acid, oxalic acid, tartaric acid, succinic acid, maleic acid, fumaric acid, gluconic acid, citric acid,

malic acid, ascorbic acid, benzoic acid, tannic acid, palmitic acid, alginic acid, polyglutamic acid, naphthalenesulfonic acid, methanesulfonic acid, p-toluenesulfonic acid, naphthalenedisulfonic acid, polygalacturonic acid, and the like; and (d) salts formed from elemental anions such as chlorine, bromine, and iodine.

3. Exemplary Utilities of the Invention: The oligonucleotides of the present invention specifically hybridize to nucleic acids (*e.g.*, mRNAs) encoding a JNK protein. The oligonucleotides of the present invention can be utilized as therapeutic compounds, as diagnostic tools or research reagents that can be incorporated into kits, and in purifications and cellular product preparations, as well as other methodologies, which are appreciated by persons of ordinary skill in the art.

A. Assays and Diagnostic Applications: The oligonucleotides of the present invention can be used to detect the presence of JNK protein-specific nucleic acids in a cell or tissue sample. For example, radiolabeled oligonucleotides can be prepared by ^{32}P labeling at the 5' end with polynucleotide kinase. (Sambrook *et al.*, *Molecular Cloning. A Laboratory Manual*, Cold Spring Harbor Laboratory Press, **1989**, Volume 2, pg. 10.59.) Radiolabeled oligonucleotides are then contacted with cell or tissue samples suspected of containing JNK protein message RNAs (and thus JNK proteins), and the samples are washed to remove unbound oligonucleotide. Radioactivity remaining in the sample indicates the presence of bound oligonucleotide, which in turn indicates the presence of nucleic acids complementary to the oligonucleotide, and can be quantitated using a scintillation counter or other routine means. Expression of nucleic acids encoding these proteins is thus detected.

Radiolabeled oligonucleotides of the present invention can also be used to perform autoradiography of tissues to

determine the localization, distribution and quantitation of JNK proteins for research, diagnostic or therapeutic purposes. In such studies, tissue sections are treated with radiolabeled oligonucleotide and washed as described above, then exposed to photographic emulsion according to routine autoradiography procedures. The emulsion, when developed, yields an image of silver grains over the regions expressing a JNK protein gene. Quantitation of the silver grains permits detection of the expression of mRNA molecules encoding these proteins and permits targeting of oligonucleotides to these areas.

Analogous assays for fluorescent detection of expression of JNK protein nucleic acids can be developed using oligonucleotides of the present invention which are conjugated with fluorescein or other fluorescent tags instead of radiolabeling. Such conjugations are routinely accomplished during solid phase synthesis using fluorescently-labeled amidites or controlled pore glass (CPG) columns. Fluorescein-labeled amidites and CPG are available from, *e.g.*, Glen Research, Sterling VA. Other means of labeling oligonucleotides are known in the art (see, *e.g.*, Ruth, Chapter 6 *In: Methods in Molecular Biology, Vol. 26: Protocols for Oligonucleotide Conjugates*, Agrawal, ed., Humana Press Inc., Totowa, NJ, **1994**, pages 167-185).

Kits for detecting the presence or absence of expression of a JNK protein may also be prepared. Such kits include an oligonucleotide targeted to an appropriate gene, *i.e.*, a gene encoding a JNK protein. Appropriate kit and assay formats, such as, *e.g.*, "sandwich" assays, are known in the art and can easily be adapted for use with the oligonucleotides of the invention. Hybridization of the oligonucleotides of the invention with a nucleic acid encoding a JNK protein can be detected by means known in the art. Such means may include conjugation of an enzyme to the oligonucleotide, radiolabelling of the oligonucleotide or any other suitable detection systems.

B. Protein Purifications: The oligonucleotides of the invention are also useful for the purification of specific Jun kinase proteins from cells that normally express a set of JNK proteins which are similar to each other in terms of their polypeptide sequences and biochemical properties. As an example, the purification of a JNK1 protein from cells that expresses JNK1, JNK2 and JNK3 proteins can be enhanced by first treating such cells with oligonucleotides that inhibit the expression of JNK2 and JNK3 and/or with oligonucleotides that increase the expression of JNK1, because such treatments will increase the relative ratio of JNK1 relative to JNK2 and JNK3. As a result, the yield of JNK1 from subsequent purification steps will be improved as the amount of the biochemically similar (and thus likely to contaminate) JNK2 and JNK3 proteins in extracts prepared from cells so treated will be diminished.

C. Biologically Active Oligonucleotides: The invention is also drawn to the administration of oligonucleotides having biological activity to cultured cells, isolated tissues and organs and animals. By "having biological activity," it is meant that the oligonucleotide functions to modulate the expression of one or more genes in cultured cells, isolated tissues or organs and/or animals. Such modulation can be achieved by an antisense oligonucleotide by a variety of mechanisms known in the art, including but not limited to transcriptional arrest; effects on RNA processing (capping, polyadenylation and splicing) and transportation; enhancement of cellular degradation of the target nucleic acid; and translational arrest (Crooke *et al.*, *Exp. Opin. Ther. Patents*, **1996** *6*, 855).

In an animal other than a human, the compositions and methods of the invention can be used to study the function of one or more genes in the animal. For example, antisense oligonucleotides have been systemically administered to rats

in order to study the role of the *N*-methyl-D-aspartate receptor in neuronal death, to mice in order to investigate the biological role of protein kinase C-a, and to rats in order to examine the role of the neuropeptide Y1 receptor in anxiety (Wahlestedt *et al.*, *Nature*, **1993**, *363*, 260; Dean *et al.*, *Proc. Natl. Acad. Sci. U.S.A.*, **1994**, *91*, 11762; and Wahlestedt *et al.*, *Science*, **1993**, *259*, 528, respectively). In instances where complex families of related proteins are being investigated, "antisense knockouts" (*i.e.*, inhibition of a gene by systemic administration of antisense oligonucleotides) may represent the most accurate means for examining a specific member of the family (see, generally, Albert *et al.*, *Trends Pharmacol. Sci.*, **1994**, *15*, 250).

The compositions and methods of the invention also have therapeutic uses in an animal, including a human, having (*i.e.*, suffering from), or known to be or suspected of being prone to having, a disease or disorder that is treatable in whole or in part with one or more nucleic acids. The term "therapeutic uses" is intended to encompass prophylactic, palliative and curative uses wherein the oligonucleotides of the invention are contacted with animal cells either *in vivo* or *ex vivo*. When contacted with animal cells *ex vivo*, a therapeutic use includes incorporating such cells into an animal after treatment with one or more oligonucleotides of the invention.

For therapeutic uses, an animal suspected of having a disease or disorder which can be treated or prevented by modulating the expression or activity of a JNK protein is, for example, treated by administering oligonucleotides in accordance with this invention. The oligonucleotides of the invention can be utilized in pharmaceutical compositions by adding an effective amount of an oligonucleotide to a suitable pharmaceutically acceptable carrier such as, *e.g.*, a diluent. Workers in the field have identified antisense, triplex and

other oligonucleotide compositions which are capable of modulating expression of genes implicated in viral, fungal and metabolic diseases. Antisense oligonucleotides have been safely administered to humans and several clinical trials are presently underway. It is thus established that oligonucleotides can be useful therapeutic instrumentalities that can be configured to be useful in treatment regimes for treatment of cells, tissues and animals, especially humans. The following U.S. patents demonstrate palliative, therapeutic and other methods utilizing antisense oligonucleotides. U. S. Patent No. 5,135,917 provides antisense oligonucleotides that inhibit human interleukin-1 receptor expression. U.S. Patent No. 5,098,890 is directed to antisense oligonucleotides complementary to the *c-myb* oncogene and antisense oligonucleotide therapies for certain cancerous conditions. U.S. Patent No. 5,087,617 provides methods for treating cancer patients with antisense oligonucleotides. U.S. Patent No. 5,166,195 provides oligonucleotide inhibitors of Human Immunodeficiency Virus (HIV). U.S. Patent No. 5,004,810 provides oligomers capable of hybridizing to herpes simplex virus Vmw65 mRNA and inhibiting replication. U.S. Patent No. 5,194,428 provides antisense oligonucleotides having antiviral activity against influenza virus. U.S. Patent No. 5,004,810 provides antisense oligonucleotides and methods using them to inhibit HTLV-III replication. U.S. Patent No. 5,286,717 provides oligonucleotides having a complementary base sequence to a portion of an oncogene. U.S. Patent No. 5,276,019 and U.S. Patent No. 5,264,423 are directed to phosphorothioate oligonucleotide analogs used to prevent replication of foreign nucleic acids in cells. U.S. Patent No. 4,689,320 is directed to antisense oligonucleotides as antiviral agents specific to cytomegalovirus (CMV). U.S. Patent No. 5,098,890 provides oligonucleotides complementary to at least a portion of the mRNA transcript of the human *c-myb* gene. U.S. Patent No.

5,242,906 provides antisense oligonucleotides useful in the treatment of latent Epstein-Barr virus (EBV) infections.

As used herein, the term "disease or disorder" (1) includes any abnormal condition of an organism or part, especially as a consequence of infection, inherent weakness, environmental stress, that impairs normal physiological functioning; (2) excludes pregnancy *per se* but not autoimmune and other diseases associated with pregnancy; and (3) includes cancers and tumors. The term "known to be or suspected of being prone to having a disease or disorder" indicates that the subject animal has been determined to be, or is suspected of being, at increased risk, relative to the general population of such animals, of developing a particular disease or disorder as herein defined. For example, a subject animal "known to be or suspected of being prone to having a disease or disorder" could have a personal and/or family medical history that includes frequent occurrences of a particular disease or disorder. As another example, a subject animal "known to be or suspected of being prone to having a disease or disorder" could have had such a susceptibility determined by genetic screening according to techniques known in the art (see, *e.g.*, U.S. Congress, Office of Technology Assessment, Chapter 5 *In: Genetic Monitoring and Screening in the Workplace*, OTA-BA-455, U.S. Government Printing Office, Washington, D.C., 1990, pages 75-99). The term "a disease or disorder that is treatable in whole or in part with one or more nucleic acids" refers to a disease or disorder, as herein defined, (1) the management, modulation or treatment thereof, and/or (2) therapeutic, curative, palliative and/or prophylactic relief therefrom, can be provided via the administration of an antisense oligonucleotide.

4. Pharmaceutical Compositions: The formulation of pharmaceutical compositions comprising the oligonucleotides of the invention, and their subsequent administration, are believed to be within the skill of those in the art.

A. Therapeutic Considerations: In general, for therapeutic applications, a patient (*i.e.*, an animal, including a human, having or predisposed to a disease or disorder) is administered one or more oligonucleotides, in accordance with the invention in a pharmaceutically acceptable carrier in doses ranging from 0.01 μg to 100 g per kg of body weight depending on the age of the patient and the severity of the disorder or disease state being treated. Further, the treatment regimen may last for a period of time which will vary depending upon the nature of the particular disease or disorder, its severity and the overall condition of the patient, and may extend from once daily to once every 20 years. In the context of the invention, the term "treatment regimen" is meant to encompass therapeutic, palliative and prophylactic modalities. Following treatment, the patient is monitored for changes in his/her condition and for alleviation of the symptoms of the disorder or disease state. The dosage of the nucleic acid may either be increased in the event the patient does not respond significantly to current dosage levels, or the dose may be decreased if an alleviation of the symptoms of the disorder or disease state is observed, or if the disorder or disease state has been ablated.

Dosing is dependent on severity and responsiveness of the disease state to be treated, with the course of treatment lasting from several days to several months, or until a cure is effected or a diminution of the disease state is achieved. Optimal dosing schedules can be calculated from measurements of drug accumulation in the body of the patient. Persons of ordinary skill can easily determine optimum dosages, dosing methodologies and repetition rates. Optimum dosages may vary depending on the relative potency of individual oligonucleotides, and can generally be estimated based on EC_{50}s found to be effective in *in vitro* and *in vivo* animal models. In general, dosage is from 0.01 μg to 100 g per kg of body weight, and may be given once or more daily, weekly, monthly

or yearly, or even once every 2 to 20 years. An optimal dosing schedule is used to deliver a therapeutically effective amount of the oligonucleotide being administered via a particular mode of administration.

The term "therapeutically effective amount," for the purposes of the invention, refers to the amount of oligonucleotide-containing pharmaceutical composition which is effective to achieve an intended purpose without undesirable side effects (such as toxicity, irritation or allergic response). Although individual needs may vary, determination of optimal ranges for effective amounts of pharmaceutical compositions is within the skill of the art. Human doses can be extrapolated from animal studies (Katocs *et al.*, Chapter 27 *In: Remington's Pharmaceutical Sciences*, 18th Ed., Gennaro, ed., Mack Publishing Co., Easton, PA, **1990**). Generally, the dosage required to provide an effective amount of a pharmaceutical composition, which can be adjusted by one skilled in the art, will vary depending on the age, health, physical condition, weight, type and extent of the disease or disorder of the recipient, frequency of treatment, the nature of concurrent therapy (if any) and the nature and scope of the desired effect(s) (Nies *et al.*, Chapter 3 *In: Goodman & Gilman's The Pharmacological Basis of Therapeutics*, 9th Ed., Hardman *et al.*, Eds., McGraw-Hill, New York, NY, **1996**).

As used herein, the term "high risk individual" is meant to refer to an individual for whom it has been determined, via, *e.g.*, individual or family history or genetic testing, has a significantly higher than normal probability of being susceptible to the onset or recurrence of a disease or disorder. As art of treatment regimen for a high risk individual, the individual can be prophylactically treated to prevent the onset or recurrence of the disease or disorder. The term "prophylactically effective amount" is meant to refer

to an amount of a pharmaceutical composition which produces an effect observed as the prevention of the onset or recurrence of a disease or disorder. Prophylactically effective amounts of a pharmaceutical composition are typically determined by the effect they have compared to the effect observed when a second pharmaceutical composition lacking the active agent is administered to a similarly situated individual.

Following successful treatment, it may be desirable to have the patient undergo maintenance therapy to prevent the recurrence of the disease state, wherein the nucleic acid is administered in maintenance doses, ranging from 0.01 μg to 100 g per kg of body weight, once or more daily, to once every 20 years. For example, in the case of in individual known or suspected of being prone to an autoimmune or inflammatory condition, prophylactic effects may be achieved by administration of preventative doses, ranging from 0.01 μg to 100 g per kg of body weight, once or more daily, to once every 20 years. In like fashion, an individual may be made less susceptible to an inflammatory condition that is expected to occur as a result of some medical treatment, *e.g.*, graft versus host disease resulting from the transplantation of cells, tissue or an organ into the individual.

In some cases it may be more effective to treat a patient with an oligonucleotide of the invention in conjunction with other traditional therapeutic modalities in order to increase the efficacy of a treatment regimen. In the context of the invention, the term "A treatment regimen" is meant to encompass therapeutic, palliative and prophylactic modalities. For example, a patient may be treated with conventional chemotherapeutic agents, particularly those used for tumor and cancer treatment. Examples of such chemotherapeutic agents include but are not limited to daunorubicin, daunomycin, dactinomycin, doxorubicin, epirubicin, idarubicin, esorubicin, bleomycin, mafosfamide,

ifosfamide, cytosine arabinoside, bis-chloroethylnitrosurea, busulfan, mitomycin C, actinomycin D, mithramycin, prednisone, hydroxyprogesterone, testosterone, tamoxifen, dacarbazine, procarbazine, hexamethylmelamine, pentamethylmelamine, mitoxantrone, amsacrine, chlorambucil, methylcyclohexylnitrosurea, nitrogen mustards, melphalan, cyclophosphamide, 6-mercaptopurine, 6-thioguanine, cytarabine (CA), 5-azacytidine, hydroxyurea, deoxycoformycin, 4-hydroxyperoxycyclophosphoramide, 5-fluorouracil (5-FU), 5-fluorodeoxyuridine (5-FUdR), methotrexate (MTX), colchicine, vincristine, vinblastine, etoposide, trimetrexate, teniposide, cisplatin and diethylstilbestrol (DES). See, generally, *The Merck Manual of Diagnosis and Therapy*, 15th Ed., pp. 1206-1228, Berkow *et al.*, Eds., Rahay, N.J., **1987**). When used with the compounds of the invention, such chemotherapeutic agents may be used individually (*e.g.*, 5-FU and oligonucleotide), sequentially (*e.g.*, 5-FU and oligonucleotide for a period of time followed by MTX and oligonucleotide), or in combination with one or more other such chemotherapeutic agents (*e.g.*, 5-FU, MTX and oligonucleotide, or 5-FU, radiotherapy and oligonucleotide).

In another preferred embodiment of the invention, a first antisense oligonucleotide targeted to a first JNK protein is used in combination with a second antisense oligonucleotide targeted to a second JNK protein in order to such JNK proteins to a more extensive degree than can be achieved when either oligonucleotide is used individually. In various embodiments of the invention, the first and second JNK proteins which are targeted by such oligonucleotides are identical, are different JNK proteins or are different isoforms of the same JNK protein.

B. Pharmaceutical Compositions: Pharmaceutical compositions for the non-parenteral administration of oligonucleotides may include sterile aqueous solutions which

may also contain buffers, diluents and other suitable additives. Pharmaceutically acceptable organic or inorganic carrier substances suitable for non-parenteral administration which do not deleteriously react with oligonucleotides can be used. Suitable pharmaceutically acceptable carriers include, but are not limited to, water, salt solutions, alcohol, polyethylene glycols, gelatin, lactose, amylose, magnesium stearate, talc, silicic acid, viscous paraffin, hydroxymethylcellulose, polyvinylpyrrolidone and the like. The pharmaceutical compositions can be sterilized and, if desired, mixed with auxiliary agents, *e.g.*, lubricants, preservatives, stabilizers, wetting agents, emulsifiers, salts for influencing osmotic pressure, buffers, colorings flavorings and/or aromatic substances and the like which do not deleteriously react with the oligonucleotide(s) of the pharmaceutical composition. Pharmaceutical compositions in the form of aqueous suspensions may contain substances which increase the viscosity of the suspension including, for example, sodium carboxymethylcellulose, sorbitol and/or dextran. Optionally, such suspensions may also contain stabilizers.

In one embodiment of the invention, an oligonucleotide is administered via the rectal mode. In particular, pharmaceutical compositions for rectal administration include foams, solutions (enemas) and suppositories. Rectal suppositories for adults are usually tapered at one or both ends and typically weigh about 2 g each, with infant rectal suppositories typically weighing about one-half as much, when the usual base, cocoa butter, is used (Block, Chapter 87 *In: Remington's Pharmaceutical Sciences*, 18th Ed., Gennaro, ed., Mack Publishing Co., Easton, PA, **1990**).

In a preferred embodiment of the invention, one or more oligonucleotides are administered via oral delivery. Pharmaceutical compositions for oral administration include powders or granules, suspensions or solutions in water or non-

aqueous media, capsules, sachets, troches, tablets or SECs (soft elastic capsules or "caplets"). Thickeners, flavoring agents, diluents, emulsifiers, dispersing aids, carrier substances or binders may be desirably added to such pharmaceutical compositions. The use of such pharmaceutical compositions has the effect of delivering the oligonucleotide to the alimentary canal for exposure to the mucosa thereof. Accordingly, the pharmaceutical composition can comprise material effective in protecting the oligonucleotide from pH extremes of the stomach, or in releasing the oligonucleotide over time, to optimize the delivery thereof to a particular mucosal site. Enteric coatings for acid-resistant tablets, capsules and caplets are known in the art and typically include acetate phthalate, propylene glycol and sorbitan monoleate.

Various methods for producing pharmaceutical compositions for alimentary delivery are well known in the art. See, generally, Nairn, Chapter 83; Block, Chapter 87; Rudnic *et al.*, Chapter 89; Porter, Chapter 90; and Longer *et al.*, Chapter 91 *In: Remington's Pharmaceutical Sciences*, 18th Ed., Gennaro, ed., Mack Publishing Co., Easton, PA, **1990**. The oligonucleotides of the invention can be incorporated in a known manner into customary pharmaceutical compositions, such as tablets, coated tablets, pills, granules, aerosols, syrups, emulsions, suspensions and solutions, using inert, non-toxic, pharmaceutically acceptable carriers (excipients). The therapeutically active compound should in each case be present here in a concentration of about 0.5% to about 95% by weight of the total mixture, *i.e.*, in amounts which are sufficient to achieve the stated dosage range. The pharmaceutical compositions are prepared, for example, by diluting the active compounds with pharmaceutically acceptable carriers, if appropriate using emulsifying agents and/or dispersing agents, and, for example, in the case where water is used as the diluent, organic solvents can be used as auxiliary solvents

if appropriate. Pharmaceutical compositions may be formulated in a conventional manner using additional pharmaceutically acceptable carriers as appropriate. Thus, the compositions may be prepared by conventional means with additional excipients such as binding agents (*e.g.*, pregelatinised maize starch, polyvinylpyrrolidone or hydroxypropyl methylcellulose); fillers (*e.g.*, lactose, microcrystalline cellulose or calcium hydrogen phosphate); lubricants (*e.g.*, magnesium stearate, talc or silica); disintegrates (*e.g.*, starch or sodium starch glycolate); or wetting agents (*e.g.*, sodium lauryl sulfate). Tablets may be coated by methods well known in the art. The preparations may also contain flavoring, coloring and/or sweetening agents as appropriate.

The pharmaceutical compositions, which may conveniently be presented in unit dosage form, may be prepared according to conventional techniques well known in the pharmaceutical industry. Such techniques include the step of bringing into association the active ingredient(s) with the pharmaceutically acceptable carrier(s). In general the pharmaceutical compositions are prepared by uniformly and intimately bringing into association the active ingredient(s) with liquid excipients or finely divided solid excipients or both, and then, if necessary, shaping the product.

Pharmaceutical compositions of the present invention suitable for oral administration may be presented as discrete units such as capsules, cachets or tablets each containing predetermined amounts of the active ingredients; as powders or granules; as solutions or suspensions in an aqueous liquid or a non-aqueous liquid; or as oil-in-water emulsions or water-in-oil liquid emulsions. A tablet may be made by compression or molding, optionally with one or more accessory ingredients. Compressed tablets may be prepared by compressing in a suitable machine, the active ingredients in a free-flowing form such as a powder or granules, optionally mixed with a binder, lubricant, inert diluent, preservative,

surface active or dispersing agent. Molded tablets may be made by molding in a suitable machine a mixture of the powdered compound moistened with an inert liquid diluent. The tablets may optionally be coated or scored and may be formulated so as to provide slow or controlled release of the active ingredients therein. Pharmaceutical compositions for parenteral, intrathecal or intraventricular administration, or colloidal dispersion systems, may include sterile aqueous solutions which may also contain buffers, diluents and other suitable additives.

C. Penetration Enhancers: Pharmaceutical compositions comprising the oligonucleotides of the present invention may also include penetration enhancers in order to enhance the alimentary delivery of the oligonucleotides. Penetration enhancers may be classified as belonging to one of five broad categories, *i.e.*, fatty acids, bile salts, chelating agents, surfactants and non-surfactants (Lee *et al.*, *Critical Reviews in Therapeutic Drug Carrier Systems*, **1991**, *8*, 91-192; Muranishi, *Critical Reviews in Therapeutic Drug Carrier Systems*, **1990**, 7:1).

1. Fatty Acids: Various fatty acids and their derivatives which act as penetration enhancers include, for example, oleic acid, lauric acid, capric acid, myristic acid, palmitic acid, stearic acid, linoleic acid, linolenic acid, dicaprate, tricaprate, recinleate, monoolein (a.k.a. 1-monooleoyl-*rac*-glycerol), dilaurin, caprylic acid, arichidonic acid, glyceryl 1-monocaprate, 1-dodecylazacycloheptan-2-one, acylcarnitines, acylcholines, mono- and di-glycerides and physiologically acceptable salts thereof (*i.e.*, oleate, laurate, caprate, myristate, palmitate, stearate, linoleate, *etc.*) (Lee *et al.*, *Critical Reviews in Therapeutic Drug Carrier Systems*, **1991**, page 92; Muranishi, *Critical Reviews in Therapeutic Drug Carrier Systems*, **1990**, *7*, 1; El-Hariri *et al.*, *J. Pharm. Pharmacol.*, **1992**, *44*, 651).

2. Bile Salts: The physiological roles of bile include the facilitation of dispersion and absorption of lipids and fat-soluble vitamins (Brunton, Chapter 38 *In: Goodman & Gilman's The Pharmacological Basis of Therapeutics*, 9th Ed., Hardman *et al.*, Eds., McGraw-Hill, New York, NY, **1996**, pages 934-935). Various natural bile salts, and their synthetic derivatives, act as penetration enhancers. Thus, the term "bile salt" includes any of the naturally occurring components of bile as well as any of their synthetic derivatives.

3. Chelating Agents: Chelating agents have the added advantage of also serving as DNase inhibitors and include, but are not limited to, disodium ethylenediaminetetraacetate (EDTA), citric acid, salicylates (*e.g.*, sodium salicylate, 5-methoxysalicylate and homovanilate), *N*-acyl derivatives of collagen, laureth-9 and *N*-amino acyl derivatives of beta-diketones (enamines)(Lee *et al.*, *Critical Reviews in Therapeutic Drug Carrier Systems*, **1991**, page 92; Muranishi, *Critical Reviews in Therapeutic Drug Carrier Systems*, **1990**, *7*, 1; Buur *et al.*, *J. Control Rel.*, **1990**, *14*, 43).

4. Surfactants: Surfactants include, for example, sodium lauryl sulfate, polyoxyethylene-9-lauryl ether and polyoxyethylene-20-cetyl ether (Lee *et al.*, *Critical Reviews in Therapeutic Drug Carrier Systems*, **1991**, page 92); and perfluorochemical emulsions, such as FC-43 (Takahashi *et al.*, *J. Pharm. Phamacol.*, **1988**, *40*, 252).

5. Non-Surfactants: Non-surfactants include, for example, unsaturated cyclic ureas, 1-alkyl- and 1-alkenylazacyclo-alkanone derivatives (Lee *et al.*, *Critical Reviews in Therapeutic Drug Carrier Systems*, **1991**, page 92); and non-steroidal anti-inflammatory agents such as diclofenac sodium, indomethacin and phenylbutazone (Yamashita *et al.*, *J. Pharm. Pharmacol.*, **1987**, *39*, 621).

D. Carrier Compounds: As used herein, "carrier compound" refers to a nucleic acid, or analog thereof, which is inert (*i.e.*, does not possess biological activity *per se*) but is recognized as a nucleic acid by *in vivo* processes that reduce the bioavailability of a nucleic acid having biological activity by, for example, degrading the biologically active nucleic acid or promoting its removal from circulation. The coadministration of a nucleic acid and a carrier compound, typically with an excess of the latter substance, can result in a substantial reduction of the amount of nucleic acid recovered in the liver, kidney or other extracirculatory reservoirs, presumably due to competition between the carrier compound and the nucleic acid for a common receptor. For example, the recovery of a partially phosphorothioated oligonucleotide in hepatic tissue is reduced when it is coadministered with polyinosinic acid, dextran sulfate, polycytidic acid or 4-acetamido-4'-isothiocyano-stilbene-2,2'-disulfonic acid (Miyao *et al.*, *Antisense Res. Dev.*, **1995**, 5, 115; Takakura *et al.*, *Antisense & Nucl. Acid Drug Dev.*, **1996**, *6*, 177).

E. Pharmaceutically Acceptable Carriers: In contrast to a carrier compound, a "pharmaceutically acceptable carrier" (excipient) is a pharmaceutically acceptable solvent, suspending agent or any other pharmacologically inert vehicle for delivering one or more nucleic acids to an animal. The pharmaceutically acceptable carrier may be liquid or solid and is selected with the planned manner of administration in mind so as to provide for the desired bulk, consistency, *etc.*, when combined with a nucleic acid and the other components of a given pharmaceutical composition. Typical pharmaceutically acceptable carriers include, but are not limited to, binding agents (*e.g.*, pregelatinised maize starch, polyvinylpyrrolidone or hydroxypropyl methylcellulose, *etc.*); fillers (*e.g.*, lactose and other sugars, microcrystalline

cellulose, pectin, gelatin, calcium sulfate, ethyl cellulose, polyacrylates or calcium hydrogen phosphate, *etc.*); lubricants (*e.g.*, magnesium stearate, talc, silica, colloidal silicon dioxide, stearic acid, metallic stearates, hydrogenated vegetable oils, corn starch, polyethylene glycols, sodium benzoate, sodium acetate, *etc.*); disintegrates (*e.g.*, starch, sodium starch glycolate, *etc.*); or wetting agents (*e.g.*, sodium lauryl sulphate, *etc.*). Sustained release oral delivery systems and/or enteric coatings for orally administered dosage forms are described in U.S. Patent No. 4,704,295; 4,556,552; 4,309,406; and 4,309,404.

F. Miscellaneous Additional Components: The compositions of the present invention may additionally contain other adjunct components conventionally found in pharmaceutical compositions, at their art-established usage levels. Thus, for example, the compositions may contain additional compatible pharmaceutically-active materials such as, *e.g.*, antipruritics, astringents, local anesthetics or anti-inflammatory agents, or may contain additional materials useful in physically formulating various dosage forms of the composition of present invention, such as dyes, flavoring agents, preservatives, antioxidants, opacifiers, thickening agents and stabilizers. However, such materials, when added, should not unduly interfere with the biological activities of the components of the compositions of the invention.

G. Colloidal Dispersion Systems: Regardless of the method by which the oligonucleotides of the invention are introduced into a patient, colloidal dispersion systems may be used as delivery vehicles to enhance the *in vivo* stability of the oligonucleotides and/or to target the oligonucleotides to a particular organ, tissue or cell type. Colloidal dispersion systems include, but are not limited to, macromolecule complexes, nanocapsules, microspheres, beads and lipid-based systems including oil-in-water emulsions,

micelles, mixed micelles and liposomes. A preferred colloidal dispersion system is a plurality of liposomes, artificial membrane vesicles which may be used as cellular delivery vehicles for bioactive agents *in vitro* and *in vivo* (Mannino *et al.*, *Biotechniques*, **1988**, *6*, 682; Blume and Cevc, *Biochem. et Biophys. Acta*, **1990**, *1029*, 91; Lappalainen *et al.*, *Antiviral Res.*, **1994**, *23*, 119; Chonn and Cullis, *Current Op. Biotech.*, **1995**, *6*, 698). It has been shown that large unilamellar vesicles (LUV), which range in size from 0.2-0.4 μm, can encapsulate a substantial percentage of an aqueous buffer containing large macromolecules. RNA, DNA and intact virions can be encapsulated within the aqueous interior and delivered to brain cells in a biologically active form (Fraley *et al.*, *Trends Biochem. Sci.*, **1981**, *6*, 77). The composition of the liposome is usually a combination of lipids, particularly phospholipids, in particular, high phase transition temperature phospholipids, usually in combination with one or more steroids, particularly cholesterol. Examples of lipids useful in liposome production include phosphatidyl compounds, such as phosphatidylglycerol, phosphatidylcholine, phosphatidylserine, sphingolipids, phosphatidylethanolamine, cerebrosides and gangliosides. Particularly useful are diacyl phosphatidylglycerols, where the lipid moiety contains from 14-18 carbon atoms, particularly from 16-18 carbon atoms, and is saturated (lacking double bonds within the 14-18 carbon atom chain). Illustrative phospholipids include phosphatidylcholine, dipalmitoylphosphatidylcholine and distearoylphosphatidylcholine.

The targeting of colloidal dispersion systems, including liposomes, can be either passive or active. Passive targeting utilizes the natural tendency of liposomes to distribute to cells of the reticuloendothelial system in organs that contain sinusoidal capillaries. Active targeting, by contrast, involves modification of the liposome by coupling thereto a

specific ligand such as a viral protein coat (Morishita *et al.*, *Proc. Natl. Acad. Sci. (U.S.A.)*, **1993**, *90*, 8474), monoclonal antibody (or a suitable binding portion thereof), sugar, glycolipid or protein (or a suitable oligopeptide fragment thereof), or by changing the composition and/or size of the liposome in order to achieve distribution to organs and cell types other than the naturally occurring sites of localization. The surface of the targeted colloidal dispersion system can be modified in a variety of ways. In the case of a liposomal targeted delivery system, lipid groups can be incorporated into the lipid bilayer of the liposome in order to maintain the targeting ligand in close association with the lipid bilayer. Various linking groups can be used for joining the lipid chains to the targeting ligand. The targeting ligand, which binds a specific cell surface molecule found predominantly on cells to which delivery of the oligonucleotides of the invention is desired, may be, for example, (1) a hormone, growth factor or a suitable oligopeptide fragment thereof which is bound by a specific cellular receptor predominantly expressed by cells to which delivery is desired or (2) a polyclonal or monoclonal antibody, or a suitable fragment thereof (*e.g.*, Fab; $F(ab')_2$) which specifically binds an antigenic epitope found predominantly on targeted cells. Two or more bioactive agents (*e.g.*, an oligonucleotide and a conventional drug; two oligonucleotides) can be combined within, and delivered by, a single liposome. It is also possible to add agents to colloidal dispersion systems which enhance the intercellular stability and/or targeting of the contents thereof.

5. Means of Administration: The present invention provides compositions comprising oligonucleotides intended for administration to an animal. For purposes of the invention, unless otherwise specified, the term "animal" is meant to encompass humans as well as other mammals, as well as reptiles, amphibians, and birds.

A. Parenteral Delivery: The term "parenteral delivery" refers to the administration of an oligonucleotide of the invention to an animal in a manner other than through the digestive canal. Means of preparing and administering parenteral pharmaceutical compositions are known in the art (see, *e.g.*, Avis, Chapter 84 *In: Remington's Pharmaceutical Sciences*, 18th Ed., Gennaro, ed., Mack Publishing Co., Easton, PA, **1990**, pages 1545-1569). Parenteral means of delivery include, but are not limited to, the following illustrative examples.

1. Intravitreal injection, for the direct delivery of drug to the vitreous humor of a mammalian eye, is described in U.S. Patent No. 5,591,720, the contents of which are hereby incorporated by reference. Means of preparing and administering ophthalmic preparations are known in the art (see, *e.g.*, Mullins *et al.*, Chapter 86 *In: Remington's Pharmaceutical Sciences*, 18th Ed., Gennaro, ed., Mack Publishing Co., Easton, PA, **1990**, pages 1581-1595).

2. Intravenous administration of antisense oligonucleotides to various non-human mammals has been described by Iversen (Chapter 26 *In: Antisense Research and Applications*, Crooke *et al.*, Eds., CBC Press, Boca Raton, FL, **1993**, pages 461-469). Systemic delivery of oligonucleotides to non-human mammals *via* intraperitoneal means has also been described (Dean *et al.*, *Proc. Natl. Acad. Sci. (U.S.A.)*, **1994**, *91*, 11766).

3. Intraluminal drug administration, for the direct delivery of drug to an isolated portion of a tubular organ or tissue (*e.g.*, such as an artery, vein, ureter or urethra), may be desired for the treatment of patients with diseases or conditions afflicting the lumen of such organs or tissues. To effect this mode of oligonucleotide administration, a catheter or cannula is surgically introduced by appropriate means. For example, for treatment of the left

common carotid artery, a cannula is inserted thereinto *via* the external carotid artery. After isolation of a portion of the tubular organ or tissue for which treatment is sought, a composition comprising the oligonucleotides of the invention is infused through the cannula or catheter into the isolated segment. After incubation for from about 1 to about 120 minutes, during which the oligonucleotide is taken up by cells of the interior lumen of the vessel, the infusion cannula or catheter is removed and flow within the tubular organ or tissue is restored by removal of the ligatures which effected the isolation of a segment thereof (Morishita *et al.*, *Proc. Natl. Acad. Sci. U.S.A.*, **1993**, *90*, 8474). Antisense oligonucleotides may also be combined with a biocompatible matrix, such as a hydrogel material, and applied directly to vascular tissue *in vivo* (Rosenberg *et al.*, U.S. Patent No. 5,593,974, issued January 14, 1997).

4. Intraventricular drug administration, for the direct delivery of drug to the brain of a patient, may be desired for the treatment of patients with diseases or conditions afflicting the brain. To effect this mode of oligonucleotide administration, a silicon catheter is surgically introduced into a ventricle of the brain of a human patient, and is connected to a subcutaneous infusion pump (Medtronic Inc., Minneapolis, MN) that has been surgically implanted in the abdominal region (Zimm *et al.*, *Cancer Research*, **1984**, *44*, 1698; Shaw, *Cancer*, **1993**, *72(11 Suppl.)*, 3416). The pump is used to inject the oligonucleotides and allows precise dosage adjustments and variation in dosage schedules with the aid of an external programming device. The reservoir capacity of the pump is 18-20 mL and infusion rates may range from 0.1 mL/h to 1 mL/h. Depending on the frequency of administration, ranging from daily to monthly, and the dose of drug to be administered, ranging from 0.01 μg to 100 g per kg of body weight, the pump reservoir may be refilled at 3-10

week intervals. Refilling of the pump is accomplished by percutaneous puncture of the self-sealing septum of the pump.

5. Intrathecal drug administration, for the introduction of a drug into the spinal column of a patient may be desired for the treatment of patients with diseases of the central nervous system. To effect this route of oligonucleotide administration, a silicon catheter is surgically implanted into the L3-4 lumbar spinal interspace of a human patient, and is connected to a subcutaneous infusion pump which has been surgically implanted in the upper abdominal region (Luer and Hatton, *The Annals of Pharmacotherapy*, **1993**, *27*, 912; Ettinger *et al.*, *Cancer*, **1978**, *41*, 1270; Yaida *et al.*, *Regul. Pept.*, **1995**, *59*, 193). The pump is used to inject the oligonucleotides and allows precise dosage adjustments and variations in dose schedules with the aid of an external programming device. The reservoir capacity of the pump is 18-20 mL, and infusion rates may vary from 0.1 mL/h to 1 mL/h. Depending on the frequency of drug administration, ranging from daily to monthly, and dosage of drug to be administered, ranging from 0.01 μg to 100 g per kg of body weight, the pump reservoir may be refilled at 3-10 week intervals. Refilling of the pump is accomplished by a single percutaneous puncture to the self-sealing septum of the pump. The distribution, stability and pharmacokinetics of oligonucleotides within the central nervous system may be followed according to known methods (Whitesell *et al.*, *Proc. Natl. Acad. Sci. (USA)*, **1993**, *90*, 4665).

To effect delivery of oligonucleotides to areas other than the brain or spinal column *via* this method, the silicon catheter is configured to connect the subcutaneous infusion pump to, *e.g.*, the hepatic artery, for delivery to the liver (Kemeny *et al.*, *Cancer*, **1993**, 71, 1964). Infusion pumps may also be used to effect systemic delivery of oligonucleotides

(Ewel *et al.*, *Cancer Research*, **1992**, *52*, 3005; Rubenstein *et al.*, J. Surg. Oncol., **1996**, 62, 194).

6. Epidermal and Transdermal Delivery, in which pharmaceutical compositions containing drugs are applied topically, can be used to administer drugs to be absorbed by the local dermis or for further penetration and absorption by underlying tissues, respectively. Means of preparing and administering medications topically are known in the art (see, *e.g.*, Block, Chapter 87 *In: Remington's Pharmaceutical Sciences*, 18th Ed., Gennaro, ed., Mack Publishing Co., Easton, PA, **1990**, pages 1596-1609).

7. Vaginal Delivery provides local treatment and avoids first pass metabolism, degradation by digestive enzymes, and potential systemic side-effects. This mode of administration may be preferred for antisense oligonucleotides targeted to pathogenic organisms for which the vagina is the usual habitat, *e.g.*, *Trichomonas vaginalis*. In another embodiment, antisense oligonucleotides to genes encoding sperm-specific antibodies can be delivered by this mode of administration in order to increase the probability of conception and subsequent pregnancy. Vaginal suppositories (Block, Chapter 87 *In: Remington's Pharmaceutical Sciences*, 18th Ed., Gennaro, ed., Mack Publishing Co., Easton, PA, 1990, pages 1609-1614) or topical ointments can be used to effect this mode of delivery.

8. Intravesical Delivery provides local treatment and avoids first pass metabolism, degradation by digestive enzymes, and potential systemic side-effects. However, the method requires urethral catheterization of the patient and a skilled staff. Nevertheless, this mode of administration may be preferred for antisense oligonucleotides targeted to pathogenic organisms, such as *T. vaginalis*, which may invade the urogenital tract.

B. Alimentary Delivery: The term "alimentary delivery" refers to the administration, directly or otherwise, to a portion of the alimentary canal of an animal. The term "alimentary canal" refers to the tubular passage in an animal that functions in the digestion and absorption of food and the elimination of food residue, which runs from the mouth to the anus, and any and all of its portions or segments, *e.g.*, the oral cavity, the esophagus, the stomach, the small and large intestines and the colon, as well as compound portions thereof such as, *e.g.*, the gastro-intestinal tract. Thus, the term "alimentary delivery" encompasses several routes of administration including, but not limited to, oral, rectal, endoscopic and sublingual/buccal administration. A common requirement for these modes of administration is absorption over some portion or all of the alimentary tract and a need for efficient mucosal penetration of the nucleic acid(s) so administered.

1. Buccal/Sublingual Administration: Delivery of a drug via the oral mucosa has several desirable features, including, in many instances, a more rapid rise in plasma concentration of the drug than via oral delivery (Harvey, Chapter 35 *In: Remington's Pharmaceutical Sciences*, 18th Ed., Gennaro, ed., Mack Publishing Co., Easton, PA, 1990, page 711). Furthermore, because venous drainage from the mouth is to the superior vena cava, this route also bypasses rapid first-pass metabolism by the liver. Both of these features contribute to the sublingual route being the mode of choice for nitroglycerin (Benet *et al.*, Chapter 1 *In: Goodman & Gilman's The Pharmacological Basis of Therapeutics*, 9th Ed., Hardman *et al.*, Eds., McGraw-Hill, New York, NY, **1996**, page 7).

2. Endoscopic Administration: Endoscopy can be used for drug delivery directly to an interior portion of the alimentary tract. For example, endoscopic retrograde

cystopancreatography (ERCP) takes advantage of extended gastroscopy and permits selective access to the biliary tract and the pancreatic duct (Hirahata *et al.*, *Gan To Kagaku Ryoho*, **1992**, *19(10 Suppl.)*, 1591). However, the procedure is unpleasant for the patient, and requires a highly skilled staff.

3. Rectal Administration: Drugs administered by the oral route can often be alternatively administered by the lower enteral route, *i.e.*, through the anal portal into the rectum or lower intestine. Rectal suppositories, retention enemas or rectal catheters can be used for this purpose and may be preferred when patient compliance might otherwise be difficult to achieve (*e.g.*, in pediatric and geriatric applications, or when the patient is vomiting or unconscious). Rectal administration may result in more prompt and higher blood levels than the oral route, but the converse may be true as well (Harvey, Chapter 35 *In: Remington's Pharmaceutical Sciences*, 18th Ed., Gennaro, ed., Mack Publishing Co., Easton, PA, **1990**, page 711). Because about 50% of the drug that is absorbed from the rectum will bypass the liver, administration by this route significantly reduces the potential for first-pass metabolism (Benet *et al.*, Chapter 1 *In: Goodman & Gilman's The Pharmacological Basis of Therapeutics*, 9th Ed., Hardman *et al.*, Eds., McGraw-Hill, New York, NY, **1996**).

4. Oral Administration: The preferred method of administration is oral delivery, which is typically the most convenient route for access to the systemic circulation. Absorption from the alimentary canal is governed by factors that are generally applicable, *e.g.*, surface area for absorption, blood flow to the site of absorption, the physical state of the drug and its concentration at the site of absorption (Benet *et al.*, Chapter 1 *In: Goodman & Gilman's The Pharmacological Basis of Therapeutics*, 9th Ed., Hardman *et*

al., Eds., McGraw-Hill, New York, NY, **1996**, pages 5-7). A significant factor which may limit the oral bioavailability of a drug is the degree of "first pass effects." For example, some substances have such a rapid hepatic uptake that only a fraction of the material absorbed enters the peripheral blood (Van Berge-Henegouwen *et al.*, *Gastroenterology*, **1977**, *73*, 300). The compositions and methods of the invention circumvent, at least partially, such first pass effects by providing improved uptake of nucleic acids and thereby, *e.g.*, causing the hepatic uptake system to become saturated and allowing a significant portion of the nucleic acid so administered to reach the peripheral circulation. Additionally or alternatively, the hepatic uptake system is saturated with one or more inactive carrier compounds prior to administration of the active nucleic acid.

The following examples illustrate the invention and are not intended to limit the same. Those skilled in the art will recognize, or be able to ascertain through routine experimentation, numerous equivalents to the specific substances and procedures described herein. Such equivalents are considered to be within the scope of the present invention.

EXAMPLES

Example 1: Synthesis of Oligonucleotides

A. General Synthetic Techniques: Oligonucleotides were synthesized on an automated DNA synthesizer using standard phosphoramidite chemistry with oxidation using iodine. ß-Cyanoethyldiisopropyl phosphoramidites were purchased from Applied Biosystems (Foster City, CA). For phosphorothioate oligonucleotides, the standard oxidation bottle was replaced by a 0.2 M solution of 3*H*-1,2-benzodithiole-3-one-1,1-dioxide in acetonitrile for the stepwise thiation of the phosphite linkages.

The synthesis of 2'-O-methyl- (a.k.a. 2'-methoxy-) phosphorothioate oligonucleotides is according to the procedures set forth above substituting 2'-O-methyl ß-cyanoethyldiisopropyl phosphoramidites (Chemgenes, Needham, MA) for standard phosphoramidites and increasing the wait cycle after the pulse delivery of tetrazole and base to 360 seconds.

Similarly, 2'-O-propyl- (a.k.a 2'-propoxy-) phosphorothioate oligonucleotides are prepared by slight modifications of this procedure and essentially according to procedures disclosed in U.S. patent application Serial No. 08/383,666, filed February 3, 1995, which is assigned to the same assignee as the instant application.

The 2'-fluoro-phosphorothioate oligonucleotides of the invention are synthesized using 5'-dimethoxytrityl-3'-phosphoramidites and prepared as disclosed in U.S. patent application Serial No. 08/383,666, filed February 3, 1995, and U.S. Patent 5,459,255, which issued October 8, 1996, both of which are assigned to the same assignee as the instant application. The 2'-fluoro-oligonucleotides were prepared using phosphoramidite chemistry and a slight modification of the standard DNA synthesis protocol (*i.e.*, deprotection was effected using methanolic ammonia at room temperature).

The 2'-methoxyethoxy oligonucleotides were synthesized essentially according to the methods of Martin *et al.* (*Helv. Chim. Acta*, **1995**, *78*, 486). For ease of synthesis, the 3' nucleotide of the 2'-methoxyethoxy oligonucleotides was a deoxynucleotide, and 2'-O-$CH_2CH_2OCH_3$-cytosines were 5-methyl cytosines, which were synthesized according to the procedures described below.

PNA antisense analogs are prepared essentially as described in U.S. Patent No. 5,539,082 and 5,539,083, both of which (1) issued July 23, 1996, and (2) are assigned to the same assignee as the instant application.

B. Purification: After cleavage from the controlled pore glass column (Applied Biosystems) and deblocking in concentrated ammonium hydroxide at 55?C for 18 hours, the oligonucleotides were purified by precipitation twice out of 0.5 M NaCl with 2.5 volumes ethanol. Analytical gel electrophoresis was accomplished in 20% acrylamide, 8 M urea, 45 mM Tris-borate buffer, pH 7.0. Oligodeoxynucleotides and their phosphorothioate analogs were judged from electrophoresis to be greater than 80% full length material.

Example 2: Assays for Oligonucleotide-Mediated Inhibition of *JNK* mRNA Expression in Human Tumor Cells

In order to evaluate the activity of potential JNK-modulating oligonucleotides, human lung carcinoma cell line A549 (American Type Culture Collection, Rockville, MD No. ATCC CCL-185) cells or other cell lines as indicated in the Examples, were grown and treated with oligonucleotides or control solutions as detailed below. After harvesting, cellular extracts were prepared and examined for specific *JNK* mRNA levels or JNK protein levels (*i.e.*, Northern or Western assays, respectively). In all cases, "% expression" refers to the amount of JNK-specific signal in an oligonucleotide-treated cell relative to an untreated cell (or a cell treated with a control solution that lacks oligonucleotide), and "% inhibition" is calculated as

100% - % Expression = % Inhibition.

Northern Assays: The mRNA expression of each JNK protein was determined by using a nucleic acid probe specifically hybridizable thereto. Nucleic acid probes specific for JNK1, JNK2 and JNK3 are described in Examples 3, 4 and 5, respectively. The probes were radiolabelled by means well known in the art (see, *e.g.*, *Short Protocols in Molecular Biology*, 2nd Ed., Ausubel *et al.*, Eds., John Wiley & Sons, New

York, **1992**, pages 3-11 to 2-3-44 and 4-17 to 4-18; Ruth, Chapter 6 *In: Methods in Molecular Biology, Vol. 26: Protocols for Oligonucleotide Conjugates*, Agrawal, ed., Humana Press Inc., Totowa, NJ, **1994**, pages 167-185; and Chapter 10 *In: Molecular Cloning: A Laboratory Manual*, 2nd Ed., Sambrook *et al.*, Eds., pages 10.1-10.70). The blots were stripped and reprobed with a ^{32}P-labeled glyceraldehyde 3-phosphate dehydrogenase (G3PDH) probe (Clontech Laboratories, Inc., Palo Alto, CA) in order to confirm equal loading of RNA and to allow the levels of JNK transcripts to be normalized with regard to the G3PDH signals.

A549 cells were grown in T-75 flasks until 80-90% confluent. At this time, the cells were washed twice with 10 mL of media (DMEM), followed by the addition of 5 mL of DMEM containing 20 μg/mL of LIPOFECTIN™ (*i.e.*, 1:1 (w/w) DOTMA/DOPE, Life Technologies, Gaithersburg, MD; DOTMA = N-[1-(2,3-dioleyoxy)propyl]-N,N,N-trimethylammonium chloride; DOPE = dioleoyl phosphatidylethanolamine). The oligonucleotides were added from a 10 μM stock solution to a final concentration of 400 nM, and the two solutions were mixed by swirling the flasks. As a control, cells were treated with LIPOFECTIN™ without oligonucleotide under the same conditions and for the same times as the oligonucleotide-treated samples. After 4 hours at 37°C, the medium was replaced with fresh DMEM containing 10% serum. The cells were allowed to recover for 18 hours. Total cellular RNA was then extracted in guanidinium, subject to gel electrophoresis and transferred to a filter according to techniques known in the art (see, *e.g.*, Chapter 7 *In: Molecular Cloning: A Laboratory Manual*, 2nd Ed., Sambrook *et al.*, Eds., pages 7.1-7.87, and *Short Protocols in Molecular Biology*, 2nd Ed., Ausubel *et al.*, Eds., John Wiley & Sons, New York, **1992**, pages 2-24 to 2-30 and 4-14 to 4-29). Filters were typically hybridized overnight to a probe specific for the particular *JNK* gene of interest in

hybridization buffer (25 mM KPO_4, pH 7.4; 5x SSC; 5x Denhardt's solution, 100 μg/ml Salmon sperm DNA and 50% formamide) (Alahari *et al.*, *Nucl. Acids Res.*, **1993**, *21*, 4079). This was followed by two washes with 1x SSC, 0.1%SDS and two washes with 0.25x SSC, 0.1% SDS. Hybridizing bands were visualized by exposure to X-OMAT AR film and quantitated using a PHOSPHORIMAGER™ essentially according to the manufacturer's instructions (Molecular Dynamics, Sunnyvale, CA).

Western Assays: A549 cells were grown and treated with oligonucleotides as described above. Cells were lysed, and protein extracts were electrophoresed (SDS-PAGE) and transferred to nitrocellulose filters by means known in the art (see, *e.g.*, Chapter 18 *In: Molecular Cloning: A Laboratory Manual*, 2nd Ed., Sambrook *et al.*, Eds., pages 18.34, 18.47-18.54 and 18.60-18.75)). The amount of each JNK protein was determined by using a primary antibody that specifically recognizes the appropriate JNK protein. The primary antibodies specific for each JNK protein are described in the appropriate Examples. The primary antibodies were detected by means well known in the art (see, *e.g.*, *Short Protocols in Molecular Biology*, 2nd Ed., Ausubel *et al.*, Eds., John Wiley & Sons, New York, **1992**, pages 10-33 to 10-35; and Chapter 18 *In: Molecular Cloning: A Laboratory Manual*, 2nd Ed., Sambrook *et al.*, Eds., pages 18.1-18.75 and 18.86-18.88) and quantitated using a PHOSPHORIMAGER™ essentially according to the manufacturer's instructions (Molecular Dynamics, Sunnyvale, CA).

Levels of JNK proteins can also be quantitated by measuring the level of their corresponding kinase activity. Such kinase assays can be done in gels *in situ* (Hibi *et al.*, *Genes & Dev.*, **1993**, 7, 2135) or after immunoprecipitation from cellular extracts (Derijard *et al.*, *Cell*, **1994**, *76*, 1025). Substrates and/or kits for such assays are commercially available from, for example, Upstate Biotechnology, Inc. (Lake

Placid, NY), New England Biolabs, Inc., (Beverly, MA) and Calbiochem-Novabiochem Biosciences, Inc., (La Jolla, CA).

Example 3: Oligonucleotide-Mediated Inhibition of JNK1 Expression

A. JNK1 oligonucleotide sequences: Table 1 lists the nucleotide sequences of a set of oligonucleotides designed to specifically hybridize to JNK1 mRNAs and their corresponding ISIS and SEQ ID numbers. The nucleotide co-ordinates of the target gene, *JNK1*, and gene target regions are also included. The nucleotide co-ordinates are derived from GenBank accession No. L26318, locus name "HUMJNK1" (see also Figure 1(A) of Derijard *et al.*, *Cell*, **1994**, *76*, 1025). The abbreviations for gene target regions are as follows: 5'-UTR, 5' untranslated region; tIR, translation initiation region; ORF, open reading frame; 3'-UTR, 3' untranslated region. The nucleotides of the oligonucleotides whose sequences are presented in Table 1 are connected by phosphorothioate linkages and are unmodified at the 2' position (*i.e.*, 2'-deoxy). It should be noted that the oligonucleotide target co-ordinate positions and gene target regions may vary within mRNAs encoding related isoforms of JNK1 (see subsection G, below).

In addition to hybridizing to human JNK1 mRNAs, the full oligonucleotide sequences of ISIS Nos. 12548 (SEQ ID NO: 17) and 12551 (SEQ ID NO: 20) hybridize to the 5' ends of mRNAs from *Rattus norvegicus* that encode a stress-activated protein kinase named "p54?" (Kyriakis *et al.*, *Nature*, 1994, *369*, 156). Specifically, ISIS 12548 (SEQ ID NO: 17) hybridizes to bases 498-517 of GenBank accession No. L27129, locus name "RATSAPKD," and ISIS 12551 (SEQ ID NO: 20) hybridizes to bases 803-822 of the same sequence. These oligonucleotides are thus preferred embodiments of the invention for investigating the role of the p54? protein kinase in rat *in vitro*, *i.e.*, in

cultured cells or tissues derived from whole animals, or *in vivo*.

B. JNK1-specific probes: In initial screenings of a set of oligonucleotides derived from the JNK1 sequence (Table 2) for biological activity, a cDNA clone of JNK1 (Derijard *et al.*, *Cell*, **1994**, *76*, 1025) was radiolabeled and used as a JNK1-specific probe in Northern blots. Alternatively, however, one or more of the oligonucleotides of Table 1 is detectably labeled and used as a JNK1-specific probe.

TABLE 1

Nucleotide Sequences of JNK1 Oligonucleotides

ISIS NO.	NUCLEOTIDE SEQUENCE (5' -> 3')	SEQ ID NO:	TARGET GENE NUCLEOTIDE CO-ORDINATES	GENE TARGET REGION
11978	ATT-CTT-TCC-ACT-CTT-CTA-TT	1	1062-1081	ORF
11979	CTC-CTC-CAA-GTC-CAT-AAC-TT	2	1094-1113	ORF
11980	CCC-GTA-TAA-CTC-CAT-TCT-TG	3	1119-1138	ORF
11981	CTG-TGC-TAA-AGG-AGA-GGG-CT	4	1142-1161	ORF
11982	ATG-ATG-GAT-GCT-GAG-AGC-CA	5	1178-1197	3'-UTR
11983	GTT-GAC-ATT-GAA-GAC-ACA-TC	6	1215-1234	3'-UTR
11984	CTG-TAT-CAG-AGG-CCA-AAG-TC	7	1241-1260	3'-UTR
11985	TGC-TGC-TTC-TAG-ACT-GCT-GT	8	1261-1280	3'-UTR
11986	AGT-CAT-CTA-CAG-CAG-CCC-AG	9	1290-1309	3'-UTR
11987	CCA-TCC-CTC-CCA-CCC-CCC-GA	10	1320-1339	3'-UTR
11988	ATC-AAT-GAC-TAA-CCG-ACT-CC	11	1340-1359	3'-UTR

11989	CAA-AAA-TAA-GAC-CAC-TGA-AT	12	1378-1397	3'-UTR
12463	CAC-GCT-TGC-TTC-TGC-TCA-TG	13	0018-0037	tIR
12464	CGG-CTT-AGC-TTC-TTG-ATT-GC	14	0175-0194	ORF
12538	CCC-GCT-TGG-CAT-GAG-TCT-GA	15	0207-0226	ORF
12539	CTC-TCT-GTA-GGC-CCG-CTT-GG	16	0218-0237	ORF
12548	ATT-TGC-ATC-CAT-GAG-CTC-CA	17	0341-0360	ORF
12549	CGT-TCC-TGC-AGT-CCT-GGC-CA	18	0533-0552	ORF
12550	GGA-TGA-CCT-CGG-GTG-CTC-TG	19	0591-0610	ORF
12551	CCC-ATA-ATG-CAC-CCC-ACA-GA	20	0646-0665	ORF
12552	CGG-GTG-TTG-GAG-AGC-TTC-AT	21	0956-0975	ORF
12553	TTT-GGT-GGT-GGA-GCT-TCT-GC	22	1006-1025	ORF
12554	GGC-TGC-CCC-CGT-ATA-ACT-CC	23	1126-1145	ORF
12555	TGC-TAA-AGG-AGA-GGG-CTG-CC	24	1139-1158	ORF
12556	AGG-CCA-AAG-TCG-GAT-CTG-TT	25	1232-1251	3'-UTR
12557	CCA-CCC-CCC-GAT-GGC-CCA-AG	26	1311-1330	3'-UTR

C. Activities of JNK1 oligonucleotides: The data from screening a set of JNK1-specific phosphorothioate oligonucleotides (Table 2) indicate the following results. Oligonucleotides showing activity in this assay, as reflected by levels of inhibition of *JNK1* mRNA levels of at least 50%, include ISIS Nos. 11982, 11983, 11985, 11987, 12463, 12464, 12538, 12539, 12548, 12549, 12550, 12552, 12553, 12554, 12555, 12556 and 12557 (SEQ ID NOS: 5, 6, 8, 10, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23, 24, 25 and 26, respectively). These oligonucleotides are thus preferred embodiments of the invention for modulating *JNK1* expression. Oligonucleotides showing levels of inhibition of *JNK1* mRNAs of at least 80% in this assay, include ISIS Nos. 11982, 12539, 12464, 12548, 12554 and 12464 (SEQ ID NOS: 5, 14, 16, 17 and 23,

respectively). These oligonucleotides are thus more preferred embodiments of the invention for modulating *JNK1* expression.

The time course of inhibition of *JNK1* mRNA expression by ISIS 12539 (SEQ ID NO: 16) is shown in Table 3. Following the 4 hour treatment with ISIS 12539, the level of inhibition of JNK1 was greater than about 85% (t=0 h), rose to about 95% inhibition at t=4h, and subsequently remained at greater than or equal to about 80% (t=12 and 48 h) or 60% (t=72 h).

TABLE 2

Activities of JNK1 Oligonucleotides

ISIS No:	SEQ ID NO:	GENE TARGET REGION	% EXPRESSION:	% INHIBITION:
11978	1	ORF	85%	15%
11979	2	ORF	90%	10%
11980	3	ORF	85%	15%
11981	4	ORF	62%	28%
11982	5	3'-UTR	13%	87%
11983	6	3'-UTR	40%	60%
11984	7	3'-UTR	53%	47%
11985	8	3'-UTR	47%	53%
11986	9	3'-UTR	90%	10%
11987	10	3'-UTR	47%	53%
11988	11	3'-UTR	78%	22%

11989	12	3'-UTR	60%	40%
12463	13	tIR	23%	77%
12464	14	ORF	18%	82%
12538	15	ORF	33%	67%
12539	16	ORF	9%	91%
12548	17	ORF	5%	95%
12549	18	ORF	28%	72%
12550	19	ORF	40%	60%
12551	20	ORF	52%	48%
12552	21	ORF	34%	66%
12553	22	ORF	25%	75%
12554	23	ORF	11%	89%
12555	24	ORF	27%	73%
12556	25	3'-UTR	41%	59%
12557	26	3'-UTR	29%	71%

TABLE 3
Time Course of Response to JNK1 Antisense Oligonucleotides (ASOs)

ISIS #	SEQ ID NO:	ASO Description	Time	Normalized % Control	% Inhibition
control	---	(LIPOFECTIN™ only)	0 h	100.0	0.0
control	---	"	4 h	100.0	0.0
control	---	"	12 h	100.0	0.0
control	---	"	48 h	100.0	0.0
control	---	"	72 h	100.0	0.0
12539	16	JNK1 active	0 h	14.1	85.9
12539	16	"	4 h	5.9	94.1
12539	16	"	12 h	11.6	88.4
12539	16	"	48 h	21.0	79.0
12539	16	"	272 h	41.5	58.5

D. Additional JNK1 oligonucleotides: The results for JNK1-specific oligonucleotides (Table 2) indicate that one of the most active phosphorothioate oligonucleotides for modulating *JNK1* expression is ISIS 12539 (SEQ ID NO: 16). As detailed in Table 4, additional oligonucleotides based on this oligonucleotide were designed to confirm and extend the findings described above.

Oligonucleotides ISIS Nos. 14320 (SEQ ID NO: 27) and 14321 (SEQ ID NO: 28) are 2'-deoxy-phosphorothioate sense strand and scrambled controls for ISIS 12539 (SEQ ID NO: 16), respectively. ISIS Nos. 15346 and 15347 are "gapmers" corresponding to ISIS 12539; both have 2'-methoxyethoxy "wings" (having phosphorothioate linkages in the case of ISIS 15346 and phosphodiester linkages in the case of ISIS 15347) and a central 2'-deoxy "gap" designed to support RNaseH activity on the target mRNA molecule. Similarly, ISIS Nos.

15348 to 15350 are "wingmers" corresponding to ISIS 12539 and have a 5' or 3' 2'-methoxyethoxy RNaseH-refractory "wing" and a 3' or 5' (respectively) 2'-deoxy "wing" designed to support RNaseH activity on the target *JNK1* mRNA.

The chemically modified derivatives of ISIS 12539 (SEQ ID NO: 16) were tested in the Northern assay described herein at concentrations of 100 and 400 nM, and the data (Table 5) indicate the following results. At 400 nM, relative to the 2'-unmodified oligonucleotide ISIS 12539, both "gapmers" (ISIS Nos. 15346 and 15347) effected inhibition of *JNK1* mRNA expression up to at least about 88% inhibition. Similarly, the four "wingmers" (ISIS Nos. 15348 to 15351) effected inhibition of *JNK1* expression of up to at least about 60 to 70% inhibition.

TABLE 4
Chemically Modified JNK1 Oligonucleotides

ISIS NO.	NUCLEOTIDE SEQUENCE (5' -> 3') AND CHEMICAL MODIFICATIONS*	SEQ ID NO:	COMMENTS
12539	$C^sT^sC^sT^sC^sT^sG^sT^sA^sG^sG^sC^sC^sC^sG^sC^sT^sT^sG^sG$	16	active
14320	$C^sC^sA^sA^sG^sC^sG^sG^sG^sC^sC^sT^sA^sC^sA^sG^sA^sG^sA^sG$	27	12539 sense control
14321	$C^sT^sT^sT^sC^sC^sG^sT^sT^sG^sG^sA^sC^sC^sC^sC^sT^sG^sG^sG$	28	scrambled control
15345	**$C^sT^sC^sT^sC^sT^sG^sT^sA^sG^sG^sC^sC^sC^sG^sC^sT^sT^sG^sG$**	16	fully 2'-methoxyethoxy
15346	**$C^sT^sC^sT^sC^sT^sG^sT^sA^sG^sG^sC^sC^sC^sG^sC^sT^sT^sG^sG$**	16	"gapmer"
15347	**$C^oT^oC^oT^oC^sT^sG^sT^sA^sG^sG^sC^sC^sC^sG^oC^oT^oT^oG^oG$**	16	"gapmer"
15348	**$C^sT^sC^sT^sC^sT^sG^sT^sA^sG^sG^sC^sC^sC^sG^sC^sT^sT^sG^sG$**	16	"wingmer"
15349	$C^sT^sC^sT^sC^sT^sG^sT^sA^sG^sG^sC^sC^sC^sG^sC^sT^sT^sG^sG$	16	"wingmer"

15351	$C^{o}T^{o}C^{o}T^{o}C^{o}T^{o}G^{o}T^{o}A^{o}G^{o}G^{s}C^{s}C^{s}C^{s}G^{s}C^{s}T^{s}T^{s}G^{s}G$	16	"wingmer"
15350	$C^{s}T^{s}C^{s}T^{s}C^{s}T^{s}G^{s}T^{s}A^{s}G^{o}G^{o}C^{o}C^{o}C^{o}G^{o}C^{o}T^{o}T^{o}G^{o}G$	16	"wingmer"
20571	$C^{s}T^{s}C^{s}T^{s}C^{s}T^{s}G^{s}T^{s}A^{s}G^{s}G^{s}\underline{C}^{s}\underline{C}^{s}\underline{C}^{s}G^{s}C^{s}T^{s}T^{s}G^{s}G$	1	fully 5-methyl-cytosine version of ISIS 15346

*Emboldened residues, 2'-methoxyethoxy- residues (others are 2'-deoxy-) including "C" residues, 5-methyl-cytosines; "^{o}", phosphodiester linkage; "^{s}", phosphorothioate linkage. --- "$\underline{C}$" residues, 2'-deoxy 5-methylcytosine residues; ---

TABLE 5

Activity of Chemically Modified JNK1 Antisense Oligonucleotides

ISIS #	SEQ ID NO:	Oligonucleotide Description *	Dose	Normalized % Control
control	---	No oligonucleotide (LIPOFECTIN™ only)	---	100.0
12539	16	JNK1 active, fully P=S &	100 nM	56.4
12539	16	fully 2'-deoxy	400 nM	26.7
15345	16	fully P=S & fully 2'-MOE	100 nM	95.4
15345	16		400 nM	89.1
15346	16	gapmer: P=S, 2'-MOE wings;	100 nM	22.6
15346	16	P=S, 2'-deoxy core	400 nM	11.0
15347	16	gapmer: P=O, 2'-MOE wings;	100 nM	27.1
15347	16	P=S, 2-deoxy core	400 nM	11.7
15348	16	wingmer: fully P=S;	100 nM	30.4
15348	16	5' 2'-MOE; 3' 2-deoxy	400 nM	32.9
15349	16	wingmer: fully P=S;	100 nM	42.5
15349	16	5' 2-deoxy; 3' 2'-MOE	400 nM	35.5
15351	16	wingmer: 5' P=O & 2'-MOE;	100 nM	45.1
15351	16	3' P=S & 2-deoxy	400 nM	39.8

15350	16	wingmer: 5' P=S & 2'-	100 nM	71.1
15350	16	deoxy; 3' P=O & 2'-MOE	400 nM	41.3

* Abbreviations: P=O, phosphodiester linkage; P=S, phosphorothioate linkage; MOE, methoxyethoxy-.

E. Dose- and sequence-dependent response to JNK1 oligonucleotides: In order to demonstrate a dose-dependent response to ISIS 12539 (SEQ ID NO: 16), different concentrations (*i.e.*, 50, 100, 200 and 400 nM) of ISIS 12539 were tested for their effect on *JNK1* mRNA levels in A549 cells (Table 6). In addition, two control oligonucleotides (ISIS 14320, SEQ ID NO: 27, sense control, and ISIS 14321, SEQ ID NO: 28, scrambled control; see also Table 4) were also applied to A549 cells in order to demonstrate the specificity of ISIS 12539. The results (Table 6) demonstrate that the response of A549 cells to ISIS 12539 is dependent on dose in an approximately linear fashion. In contrast, neither of the control oligonucleotides effect any consistent response on *JNK1* mRNA levels.

F. Western Assays: In order to assess the effect of oligonucleotides targeted to *JNK1* mRNAs on JNK1 protein levels, Western assays were performed essentially as described above in Example 2, with the following exception(s) and/or modification(s). A primary antibody that specifically binds to JNK1 (catalog No. sc-474-G) was purchased from Santa Cruz Biotechnology, Inc. (Santa Cruz, CA; other JNK1-specific antibodies are available from StressGen Biotechnologies, Inc., Victoria, BC, Canada; and Research Diagnostics, Inc., Flanders, NJ). In this experiment, cells were grown and treated with oligonucleotide at 300 nM for the initial 20 hours and then at 200 nM for 4 hours. At t=48 h, aliquots were removed for Northern and Western analyses, and fresh media was added to the cells. Aliquots for analysis were also taken at t=72 h. The samples from t=48 h and t=72 h were

analyzed using the Northern and Western assays described above.

TABLE 6
Dose-Dependent Responses to JNK1 Antisense Oligonucleotides

ISIS #	SEQ ID NO:	Oligonucleotide Description	Dose	Normalized % Control
control	---	No oligonucleotide (LIPOFECTIN™ only)	---	100.0
12539	16	JNK1 active	50 nM	70.3
12539	16	"	100 nM	51.6
12539	16	"	200 nM	22.4
12539	16	"	400 nM	11.1
14320	27	12539 sense control	50 nM	103.6
14320	27	"	100 nM	76.3
14320	27	"	200 nM	98.9
14320	27	"	400 nM	97.1
14321	28	12539 scrambled control	50 nM	91.8
14321	28	"	100 nM	94.1
14321	28	"	200 nM	100.2
14321	28	"	400 nM	79.2

The data (Table 7) indicate the following results. In this assay, at t=48 h, oligonucleotides showing a level of mRNA % inhibition from > about 70% to about 100% include ISIS Nos. 12539 (phosphorothioate linkages), 15346 and 15347 ("gapmers"), and 15348 and 15351 (5' "wingmers") (SEQ ID NO: 16). Oligonucleotides showing levels of mRNA inhibition of from ≥ about 90% to about 100% of *JNK1* mRNAs in this assay include ISIS Nos. 12539, 15345 AND 15346 (SEQ ID NO: 16). The oligonucleotides tested showed approximately parallel levels of JNK1 protein inhibition; ISIS Nos. 12539, 15346-15348 and 15351 effected levels of protein inhibition ≥ about 40%, and ISIS Nos. 12539, 15346 and 15347 effected levels of protein inhibition ≥ about 55%.

At t=72 h, oligonucleotides showing a level of mRNA % inhibition from > about 70% to about 100% include ISIS Nos. 12539 (phosphorothioate linkages), 15346 and 15347 ("gapmers"), and 15348 (5' "wingmers") (SEQ ID NO: 16). Oligonucleotides showing levels of mRNA inhibition of from ≥ about 90% to about 100% of *JNK1* mRNAs at this point in the assay include ISIS Nos. 12539 and 15346 (SEQ ID NO: 16). Overall, the oligonucleotides tested showed higher levels of JNK1 protein inhibition at this point in the assay. With the exception of the fully 2'-methoxyethoxy-modified ISIS 15345, all of the oligonucleotides in Table 7 effect ≥ about 40% protein inhibition. ISIS Nos. 12539, 15346-15348 and 15351 effected levels of protein inhibition ≥ about 60%, and ISIS Nos. 12539, 15346 and 15347 effected levels of protein inhibition ≥ about 70%.

TABLE 7
Modulation of *JNK1* mRNA and JNK1 Protein Levels by Modified JNK1 Antisense Oligonucleotides

ISIS #	SEQ ID NO:	RNA % Control	RNA % Inhibition	Protein % Control	Protein % Inhibition
			t = 48 h		
control	---	100.0	0.0	100.0	0.0
12539	16	6.7	93.3	44.3	55.7
15345	16	70.3	29.7	105.0	(0.0)
15346	16	4.3	95.7	42.7	57.3
15347	16	7.9	92.1	38.8	61.2
15348	16	24.3	75.7	58.3	41.7
15349	16	63.1	36.9	69.5	30.5
15350	16	49.2	50.8	71.7	28.3
15351	16	26.9	73.1	52.4	47.6
			t = 72 h		
control	16	100.0	0.0	100.0	0.0
12539	16	11.7	88.3	29.2	70.8

15345	16	187.4	(0.0)	87.8	12.2
15346	16	10.6	89.4	25.7	74.3
15347	16	8.2	81.8	28.4	71.6
15348	16	28.0	72.0	41.7	58.3
15349	16	52.0	48.0	56.5	43.5
15350	16	54.4	45.6	58.4	41.6
15351	16	46.1	53.9	37.0	63.0

G. Oligonucleotides specific for JNK1 isoforms: Subsequent to the initial descriptions of JNK1 (Derijard *et al.*, *Cell*, **1994**, *76*, 1025), cDNAs encoding related isoforms of JNK1 were cloned and their nucleotide sequences determined (Gupta *et al.*, *EMBO Journal*, **1996**, *15*, 2760). In addition to JNK1-a1 (GenBank accession No. L26318, locus name "HUMJNK1"), which encodes a polypeptide having an amino acid sequence identical to that of JNK1, the additional isoforms include JNK1-a2 (GenBank accession No. U34822, locus name "HSU34822"), JNK1-ß1 (GenBank accession No. U35004, locus name "HSU35004") and JNK1-ß2 (GenBank accession No. U35005, locus name "HSU35005"). The four isoforms of JNK1, which probably arise from alternative mRNA splicing, may each interact with different transcription factors or sets of transcription factors (Gupta *et al.*, *EMBO Journal*, **1996**, *15*, 2760). As detailed below, the oligonucleotides of the invention are specific for certain members or sets of these isoforms of JNK1.

In the ORFs of mRNAs encoding JNK1/JNK1-a1 and JNK1-a2, nucleotides (nt) 631-665 of JNK1/JNK1-a1 (Genbank accession No. L26318) and nt 625-659 of JNK1-a2 (Genbank accession No. U34822) have the sequence shown below as SEQ ID NO: 63, whereas, in the ORFs of mRNAs encoding JNK1-ß1 and JNK1-ß2, nt 631-665 of JNK1-ß1 (GenBank accession No. U35004) and nt 626-660 of JNK1-ß2 (GenBank accession No. U35005) have the sequence shown below as SEQ ID NO: 64. For purposes of illustration, SEQ ID NOS: 63 and 64 are shown aligned with

each other (vertical marks, "|," indicate bases that are identical in both sequences):

```
5'-AACGTGGATTTATGGTCTGTGGGGTGCATTATGGG        SEQ ID NO: 63
   ||||| ||  | ||||| || |||||||| |||||
5'-AACGTTGACATTTGGTCAGTTGGGTGCATCATGGG        SEQ ID NO: 64
```

Due to this divergence between the a and b JNK1 isoforms, antisense oligonucleotides derived from the reverse complement of SEQ ID NO: 63 (*i.e.*, SEQ ID NO: 65, see below) can be used to modulate the expression of JNK1/JNK1-a1 and JNK1-a2 without significantly effecting the expression of JNK1-ß1 and JNK1-ß2. In like fashion, antisense oligonucleotides derived from the reverse complement of SEQ ID NO: 64 (*i.e.*, SEQ ID NO: 66, see below) can be selected and used to modulate the expression of JNK1-ß1 and JNK1-ß2 without significantly effecting the expression of JNK1/JNK1-a1 and JNK1-a2. As an example, an oligonucleotide having a sequence derived from SEQ ID NO: 65 but not to SEQ ID NO: 66 is specifically hybridizable to mRNAs encoding JNK1/JNK1-a1 and JNK1-a2 but not to those encoding JNK1-ß1 and JNK1-ß2:

```
5'-CCCATAATGCACCCCACAGACCATAAATCCACGTT        SEQ ID NO: 65
   ||||| |||||||| || |||| | | || |||||
5'-CCCATGATGCACCCAACTGACCAAATGTCAACGTT        SEQ ID NO: 66
```

As a further example, in the ORFs of mRNAs encoding JNK1/JNK1-a1 and JNK1-a2, nt 668-711 of JNK1/JNK1-a1 (Genbank accession No. L26318) and nt 662-705 of JNK1-a2 (Genbank accession No. U34822) have the sequence shown below as SEQ ID NO: 67, whereas, in the ORFs of mRNAs encoding JNK1-ß1 and JNK1-ß2, nt 668-711 of JNK1-ß1 (GenBank accession No. U35004) and nt 663-706 of JNK1-ß2 (GenBank accession No. U35005) have the sequence shown below as SEQ ID NO: 68. For purposes of illustration, SEQ ID NOS: 67 and 68 are shown aligned with each other as follows:

5'-AAATGGTTTGCCACAAAATCCTCTTTCCAGGAAGGGACTATATT SEQ ID NO: 67
||||| | | || ||||| | || |||||
5'-AAATGATCAAAGGTGGTGTTTTGTTCCCAGGTACAGATCATATT SEQ ID NO: 68

Due to this divergence between the a and b JNK1 isoforms, antisense oligonucleotides derived from the reverse complement of SEQ ID NO: 67 (*i.e.*, SEQ ID NO: 69, see below) are specifically hybridizable to mRNAs encoding, and may be selected and used to modulate the expression of, JNK1/JNK1-a1 and JNK1-a2 without significantly effecting the expression of JNK1-ß1 and JNK1-ß2. In like fashion, antisense oligonucleotides derived from the reverse complement of SEQ ID NO: 68 (*i.e.*, SEQ ID NO: 70, see below) are specifically hybridizable to mRNAs encoding, and may be selected and used to modulate the expression of, can be selected and used to modulate the expression of JNK1-ß1 and JNK1-ß2 without significantly effecting the expression of JNK1/JNK1-a1 and JNK1-a2:

5'-AATATAGTCCCTTCCTGGAAAGAGGATTTTGTGGCAAACCATTT SEQ ID NO: 69
||||| || | ||||| || | | | |||||
5'-AATATGATCTGTACCTGGGAACAAAACACCACCTTTGATCATTT SEQ ID NO: 70

In the case of the carboxyl terminal portion of the JNK1 isoforms, JNK1/JNK1-a1 shares identity with JNK1-ß1; similarly, JNK1-a2 and JNK1-ß2 have identical carboxy terminal portions. The substantial differences in the amino acid sequences of these isoforms (5 amino acids in JNK1/JNK1-a1 and JNK1-ß1 are replaced with 48 amino acids in JNK1-a2 and JNK1-ß2) result from a slight difference in nucleotide sequence that shifts the reading frame. Specifically, in the ORFs of mRNAs encoding JNK1/JNK1-a1 and JNK1-ß1, nt 1144-1175 of JNK1/JNK1-a1 (Genbank accession No. L26318) and JNK1-ß1 (Genbank accession No. U35004) have the sequence shown below as SEQ ID NO: 71, whereas, in the ORFs of mRNAs encoding JNK1-a2 and JNK1-ß2, nt 1138-1164 of JNK1-a2 (GenBank accession No. U34822) and nt 1139-1165 of JNK1-ß2 (GenBank accession No.

U35005) have the sequence shown below as SEQ ID NO: 72. For purposes of illustration, SEQ ID NOS: 71 and 72 are shown aligned with each other (dashes, A-," indicate bases that are absent in the indicated sequence, and emboldened bases indicate the stop codon for the JNK1/JNK1-a1 and JNK1-ß1 ORFs):

```
5'-CCCTCTCCTTTAGCACAGGTGCAGCAGTGATC          SEQ ID NO: 71
   ||||||||||||||     ||||||||||||||
5'-CCCTCTCCTTTAG-----GTGCAGCAGTGATC          SEQ ID NO: 72
```

Due to this divergence between the JNK1 isoforms, antisense oligonucleotides derived from the reverse complement of SEQ ID NO: 71 (*i.e.*, SEQ ID NO: 73, see below) are specifically hybridizable to mRNAs encoding, and may be selected and used to modulate the expression of, JNK1/JNK1-a1 and JNK1-ß1 without significantly effecting the expression of JNK1-a2 and JNK1-ß2. In like fashion, antisense oligonucleotides derived from the reverse complement of SEQ ID NO: 72 (*i.e.*, SEQ ID NO: 74, see below) are specifically hybridizable to mRNAs encoding, and may be selected and used to modulate the expression of, JNK1-a2 and JNK1-ß2 without significantly effecting the expression of JNK1/JNK1-a1 and JNK1-ß1:

```
5'-GATCACTGCTGCACCTGTGCTAAAGGAGAGGG          SEQ ID NO: 73
   ||||||||||||||     ||||||||||||
5'-GATCACTGCTGCAC-----CTAAAGGAGAGGG          SEQ ID NO: 74
```

In preferred embodiments, such isoform-specific oligonucleotides such as are described above are methoxyethoxy "gapmers" or "wingmers" in which the RNase H-sensitive "gap" or "wing" is positioned so as to overlap a region of nonidentity in the above antisense sequences, *i.e.*, SEQ ID NOS: 65, 66, 69, 70, 73 and 74.

Example 4: Oligonucleotide-Mediated Inhibition of JNK2 Expression

A. JNK2 oligonucleotide sequences: Table 8 lists the nucleotide sequences of oligonucleotides designed to specifically hybridize to JNK2 mRNAs and the corresponding ISIS and SEQ ID numbers thereof. The target gene nucleotide co-ordinates and gene target region are also included. The nucleotide co-ordinates are derived from GenBank accession No. L31951, locus name "HUMJNK2" (see also Figure 1(A) of Sluss *et al.*, *Mol. Cel. Biol.*, **1994**, *14*, 8376, and Kallunki *et al.*, *Genes & Development*, **1994**, *8*, 2996). The abbreviations for gene target regions are as follows: 5'-UTR, 5' untranslated region; tIR, translation initiation region; ORF, open reading frame; 3'-UTR, 3' untranslated region. The nucleotides of the oligonucleotides whose sequences are presented in Table 8 are connected by phosphorothioate linkages and are unmodified at the 2' position (*i.e.*, 2-deoxy). It should be noted that the oligonucleotide target co-ordinate positions and gene target regions may vary within mRNAs encoding related isoforms of JNK2 (see subsection G, below).

In addition to hybridizing to human JNK2 mRNAs, the full oligonucleotide sequence of ISIS No. 12562 (SEQ ID NO: 33) hybridizes to the ORF of mRNAs from *Rattus norvegicus* that encode a stress-activated protein kinase named "p54a2" (Kyriakis *et al.*, *Nature*, **1994**, *369*, 156). Specifically, ISIS 12562 (SEQ ID NO: 33) hybridizes to bases 649-668 of GenBank accession No. L27112, locus name "RATSAPKB." This oligonucleotide is thus a preferred embodiment of the invention for investigating the role of the p54a2 protein kinase in rat *in vitro*, *i.e.*, in cultured cells or tissues derived from whole animals, or *in vivo*.

B. JNK2-specific probes: In initial screenings of a set of oligonucleotides derived from the JNK2 sequence (Table 9) for biological activity, a cDNA clone of JNK2 (Kallunki *et*

al., *Genes & Development*, **1994**, *8*, 2996) was radiolabeled and used as a JNK2-specific probe in Northern blots. Alternatively, however, one or more of the oligonucleotides of Table 8 is detectably labeled and used as a JNK2-specific probe.

C. Activities of JNK2 oligonucleotides: The data from screening a set of JNK2-specific phosphorothioate oligonucleotides (Table 9) indicate the following results. Oligonucleotides showing activity in this assay, as reflected by levels of inhibition of *JNK2* mRNA levels of at least 50%, include ISIS Nos. 12558, 12559, 12560, 12563, 12564, 12565, 12566, 12567, 12568, 12569 and 12570 (SEQ ID NOS: 29, 30, 31, 34, 35, 36, 37, 38, 39, 40 and 41, respectively). These oligonucleotides are thus preferred embodiments of the invention for modulating *JNK2* expression. Oligonucleotides showing levels of *JNK2* mRNAs of at least 80% in this assay, include ISIS Nos. 12558, 12560, 12565, 12567, 12568 and 12569 (SEQ ID NOS: 29, 31, 36, 38, 39 and 40, respectively). These oligonucleotides are thus more preferred embodiments of the invention for modulating *JNK2* expression.

The time course of inhibition of *JNK2* mRNA expression by ISIS 12560 (SEQ ID NO: 31) is shown in Table 10. Following the 4 hour treatment with ISIS 12560, the level of inhibition of JNK2 was greater than or equal to about 80% for at least about 12 hours and greater than or equal to about 60% up to at least about t=48 h.

TABLE 8
Nucleotide Sequences of JNK2 Oligonucleotides

ISIS NO.	NUCLEOTIDE SEQUENCE (5' -> 3')	SEQ ID NO:	TARGET GENE NUCLEOTIDE CO-ORDINATES	GENE TARGET REGION
12558	GTT-TCA-GAT-CCC-TCG-CCC-GC	29	0003-0022	5'-UTR

	12559	TGC-AGC-ACA-AAC-AAT-CCC-TT	30	0168-0187	ORF
	12560	GTC-CGG-GCC-AGG-CCA-AAG-TC	31	0563-0582	ORF
	12561	CAG-GAT-GAC-TTC-GGG-CGC-CC	32	0633-0652	ORF
	12562	GCT-CTC-CCA-TGA-TGC-AAC-CC	33	0691-0710	ORF
5	12563	ATG-GGT-GAC-GCA-GAG-CTT-CG	34	0997-1016	ORF
	12564	CTG-CTG-CAT-CTG-AAG-GCT-GA	35	1180-1199	ORF
	12565	TGA-GAA-GGA-GTG-GCG-TTG-CT	36	1205-1224	ORF
	12566	TGC-TGT-CTG-TGT-CTG-AGG-CC	37	1273-1292	ORF
	12567	GGT-CCC-GTC-GAG-GCA-TCA-AG	38	1295-1314	ORF
10	12568	CAT-TTC-AGG-CCC-ACG-GAG-GT	39	1376-1395	3'-UTR
	12569	GGT-CTG-AAT-AGG-GCA-AGG-CA	40	1547-1566	3'-UTR
	12570	GGG-CAA-GTC-CAA-GCA-AGC-AT	41	1669-1688	3'-UTR

TABLE 9
Activities of JNK2 Oligonucleotides

15	ISIS NO.	SEQ ID NO:	GENE TARGET REGION	% EXPRESSION	% INHIBITION
	12558	29	5'-UTR	15%	85%
	12559	30	ORF	28%	72%
	12560	31	ORF	11%	89%
20	12561	32	ORF	60%	40%
	12562	33	ORF	89%	11%
	12563	34	ORF	22%	78%
	12564	35	ORF	28%	72%

12565	36	ORF	19%	81%
12566	37	ORF	42%	58%
12567	38	ORF	18%	82%
12568	39	3'-UTR	20%	80%
12569	40	3'-UTR	13%	87%
12570	41	3'-UTR	24%	76%

TABLE 10
Time Course of Response to JNK2 Antisense Oligonucleotides (ASOs)

ISIS #	SEQ ID NO:	ASO Description	Time	Normalized % Control	% Inhibition
control	---	(LIPOFECTIN™ only)	0 h	100.0	0.0
control	---	"	4 h	100.0	0.0
control	---	"	12 h	100.0	0.0
control	---	"	48 h	100.0	0.0
control	---	"	72 h	100.0	0.0
12560	31	JNK2 active	0 h	20.2	79.8
12560	31	"	4 h	11.1	88.9
12560	31	"	12 h	21.8	78.2
12560	31	"	48 h	42.7	57.3
12560	31	"	72 h	116.8	(0.0)

D. Additional JNK2 oligonucleotides: The results for JNK2-specific oligonucleotides (Table 9) indicate that one of the most active phosphorothioate oligonucleotides for modulating *JNK2* expression is ISIS 12560 (SEQ ID NO: 31). As detailed in Table 11, additional oligonucleotides based on this oligonucleotide were designed to confirm and extend the findings described above.

Oligonucleotides ISIS Nos. 14318 (SEQ ID NO: 42) and 14319 (SEQ ID NO: 43) are 2'-deoxy-phosphorothioate sense strand and scrambled controls for ISIS 12560 (SEQ ID NO: 31), respectively. ISIS Nos. 15353 and 15354 are "gapmers" corresponding to ISIS 12560; both have 2'-methoxyethoxy "wings" (having phosphorothioate linkages in the case of ISIS 15353 and phosphodiester linkages in the case of ISIS 15354) and a central 2'-deoxy "gap" designed to support RNaseH activity on the target mRNA molecule. Similarly, ISIS Nos. 15355 to 15358 are "wingmers" corresponding to ISIS 12560 and have a 5' or 3' 2'-methoxyethoxy RNaseH-refractory "wing" and a 3' or 5' (respectively) 2-deoxy "wing" designed to support RNaseH activity on the target *JNK2* mRNA.

The chemically modified derivatives of ISIS 12560 (SEQ ID NO: 31) were tested in the Northern assay described herein at concentrations of 100 and 400 nM, and the data (Table 12) indicate the following results. At 400 nM, relative to the 2'-unmodified oligonucleotide ISIS 12560, both "gapmers" (ISIS Nos. 15353 and 15354) effected approximately 80% inhibition of *JNK2* mRNA expression. Similarly, the four "wingmers" (ISIS Nos. 15355 to 15358) effected 70-90% inhibition of *JNK2* expression.

E. Dose- and sequence-dependent response to JNK2 oligonucleotides: In order to demonstrate a dose-dependent response to ISIS 12560 (SEQ ID NO: 31), different concentrations (*i.e.*, 50, 100, 200 and 400 nM) of ISIS 12560 were tested for their effect on *JNK2* mRNA levels in A549 cells

(Table 13). In addition, two control oligonucleotides (ISIS 14318, SEQ ID NO: 42, sense control, and ISIS 14319, SEQ ID NO: 43, scrambled control; see also Table 11) were also applied to A549 cells in order to demonstrate the specificity of ISIS 12560. The results (Table 12) demonstrate that the response of A549 cells to ISIS 12539 is dependent on dose in an approximately linear fashion. In contrast, neither of the control oligonucleotides effect any consistent response on *JNK2* mRNA levels.

TABLE 11
Chemically Modified JNK2 Oligonucleotides

ISIS NO.	NUCLEOTIDE SEQUENCE (5' -> 3') AND CHEMICAL MODIFICATIONS*	SEQ ID NO:	COMMENTS
12560	$G^sT^sC^sC^sG^sG^sG^sC^sC^sA^sG^sG^sC^sC^sA^sA^sA^sG^sT^sC$	31	active
14318	$G^sA^sC^sT^sT^sT^sG^sG^sC^sC^sT^sG^sG^sC^sC^sC^sG^sG^sA^sC$	42	12560 sense control
14319	$G^sT^sG^sC^sG^sC^sG^sC^sG^sA^sG^sC^sC^sC^sG^sA^sA^sA^sT^sC$	43	scrambled control
15352	$\mathbf{G^sT^sC^sC^sG^sG^sG^sC^sC^sA^sG^sG^sC^sC^sA^sA^sA^sG^sT^sC}$	31	fully 2'-methoxyethoxy
15353	$\mathbf{G^sT^sC^sC^sG}G^sG^sG^sC^sC^sA^sG^sG^sC^sC^s\mathbf{A^sA^sA^sG^sT^sC}$	31	"gapmer"
15354	$\mathbf{G^oT^oC^oC^oG}^sG^sG^sC^sC^sA^sG^sG^sC^sC^s\mathbf{A^oA^oA^oG^oT^oC}$	31	"gapmer"
15355	$\mathbf{G^sT^sC^sC^sG^sG^sG^sC^sC^sA^sG}^sG^sC^sC^sA^sA^sA^sG^sT^sC$	31	"wingmer"
15356	$G^sT^sC^sC^sG^sG^sG^sC^sC^s\mathbf{A^sG^sG^sC^sC^sA^sA^sA^sG^sT^sC}$	31	"wingmer"
15358	$\mathbf{G^oT^oC^oC^oG^oG^oG^oC^oC^oA^oG}^sG^sC^sC^sA^sA^sA^sG^sT^sC$	31	"wingmer"
15357	$G^sT^sC^sC^sG^sG^sG^sC^sC^s\mathbf{A^oG^oG^oC^oC^oA^oA^oA^oG^oT^oC}$	31	"wingmer"

20572	$G^{s}T^{s}C^{s}C^{s}G^{s}G^{s}G^{s}\underline{C}^{s}\underline{C}^{s}A^{s}G^{s}G^{s}\underline{C}^{s}\underline{C}^{s}A^{s}A^{s}A^{s}G^{s}T^{s}C$	31	fully 5-methyl-cytosine version of ISIS 15353

*Emboldened residues, 2'-methoxyethoxy- residues (others are 2'-deoxy-) including "**C**" residues, 5-methyl-cytosines; "^{o}", phosphodiester linkage; "^{s}", phosphorothioate linkage.

--- "$\underline{C}$" residues, 2'-deoxy 5-methylcytosine residues; ---

TABLE 12
Activity of Chemically Modified JNK2 Antisense Oligonucleotides

ISIS #	SEQ ID NO:	Oligonucleotide Description	Dose	Normalized % Control
control	---	No oligonucleotide (LIPOFECTIN™ only)	---	100.0
12560	31	JNK2 active, fully P=S & fully 2-deoxy	100 nM	62.1
12560	31		400 nM	31.4
15352	31	fully P=S & fully 2'-MOE	100 nM	132.4
15352	31		400 nM	158.4
15353	31	gapmer: P=S, 2'-MOE wings; P=S, 2-deoxy core	100 nM	56.7
15353	31		400 nM	21.2
15354	31	gapmer: P=O, 2'-MOE wings; P=S, 2-deoxy core	100 nM	38.3
15354	31		400 nM	17.1
15355	31	wingmer: fully P=S; 5' 2'-MOE; 3' 2-deoxy	100 nM	61.3
15355	31		400 nM	29.1
15356	31	wingmer: fully P=S; 5' 2-deoxy; 3' 2'-MOE	100 nM	38.6
15356	31		400 nM	11.0
15358	31	wingmer: 5' P=O & 2'-MOE; 3' P=S & 2-deoxy	100 nM	47.4
15358	31		400 nM	29.4
15357	31	wingmer: 5' P=S & 2'-deoxy; 3' P=O & 2'-MOE	100 nM	42.8
15357	31		400 nM	13.7

TABLE 13
Dose-Dependent Responses to JNK2 Antisense Oligonucleotides

ISIS #	SEQ ID NO:	Oligonucleotide Description	Dose	Normalized % Control
control	---	No oligonucleotide (LIPOFECTIN™ only)	---	100.0
12560	31	JNK2 active	50 nM	68.1
12560	31	"	100 nM	50.0
12560	31	"	200 nM	25.1
12560	31	"	400 nM	14.2
14318	42	12560 sense control	50 nM	87.1
14318	42	"	100 nM	89.8
14318	42	"	200 nM	92.1
14318	42	"	400 nM	99.6
14319	43	12560 scrambled control	50 nM	90.4
14319	43	"	100 nM	93.7
14319	43	"	200 nM	110.2
14319	43	"	400 nM	100.0

F. Western Assays: In order to assess the effect of oligonucleotides targeted to *JNK2* mRNAs on JNK2 protein levels, Western assays are performed essentially as described above in Examples 2 and 3. A primary antibody that specifically binds to JNK2 is purchased from, for example, Santa Cruz Biotechnology, Inc., Santa Cruz, CA; Upstate Biotechnology, Inc., Lake Placid, NY; StressGen Biotechnologies, Inc., Victoria, BC, Canada; or Research Diagnostics, Inc., Flanders, NJ.

G. Oligonucleotides specific for JNK2 isoforms: Subsequent to the initial descriptions of JNK2 (Sluss *et al.*, *Mol. Cel. Biol.*, **1994**, *14*, 8376; Kallunki *et al.*, *Genes & Development*, **1994**, *8*, 2996; GenBank accession No. HSU09759, locus name "U09759"), cDNAs encoding related isoforms of JNK2 were cloned and their nucleotide sequences determined (Gupta

et al., *EMBO Journal*, **1996**, *15*, 2760). In addition to JNK2-a2 (GenBank accession No. L31951, locus name "HUMJNK2"), which encodes a polypeptide having an amino acid sequence identical to that of JNK2, the additional isoforms include JNK2-a1 (GenBank accession No. U34821, locus name "HSU34821"), JNK2-ß1 (GenBank accession No. U35002, locus name "HSU35002") and JNK2-ß2 (GenBank accession No. U35003, locus name "HSU35003"). The four isoforms of JNK2, which probably arise from alternative mRNA splicing, may each interact with different transcription factors or sets of transcription factors (Gupta *et al.*, *EMBO Journal*, **1996**, *15*, 2760). As detailed below, the oligonucleotides of the invention are specific for certain members or sets of these isoforms of JNK2.

In the ORFs of mRNAs encoding JNK2/JNK2-a2 and JNK2-a1, nucleotides (nt) 689-748 of JNK2/JNK2-a2 (GenBank accession No. L31951) and nt 675-734 of JNK2-a1 (GenBank accession No. U34821) have the sequence shown below as SEQ ID NO: 75, whereas, in the ORFs of mRNAs encoding JNK2-ß1 and JNK2-ß2, nt 653-712 of JNK2-ß1 (GenBank accession No. U35002) and nt 665-724 of JNK2-ß2 (GenBank accession No. U35003) have the sequence shown below as SEQ ID NO: 76. For purposes of illustration, SEQ ID NOS: 75 and 76 are shown aligned with each other (vertical marks, "|," indicate bases that are identical in both sequences):

SEQ ID NO: 75

```
5'-GTGGGTTGCATCATGGGAGAGCTGGTGAAAGGTTGTGTGATATTCCAAGGCACTGACCAT
   || || |||||||||| ||| |||| |  || | |||| || | ||| ||
5'-GTCGGGTGCATCATGGCAGAAATGGTCCTCCATAAAGTCCTGTTCCCGGGAAGAGACTAT
```

SEQ ID NO: 76

Due to this divergence between the a and b JNK2 isoforms, antisense oligonucleotides derived from the reverse complement of SEQ ID NO: 75 (*i.e.*, SEQ ID NO: 77, see below) are specifically hybridizable to, and may be selected and used to modulate the expression of, JNK2/JNK2-a2 and JNK2-a1 without significantly effecting the expression of JNK1-ß1 and JNK1-ß2. In like fashion, antisense oligonucleotides derived from the

reverse complement of SEQ ID NO: 76 (*i.e.*, SEQ ID NO: 78, see below) are specifically hybridizable to, and may be selected and used to modulate the expression of, JNK2-ß1 and JNK2-ß2 without significantly effecting the expression of JNK2/JNK2-a2 and JNK2-a1. As an example, an oligonucleotide having a sequence derived from SEQ ID NO: 77 but not from SEQ ID NO: 78 is specifically hybridizable to, mRNAs encoding JNK1/JNK1-a1 and JNK1-a2 but not to those encoding JNK2-ß1 and JNK2-ß2:

SEQ ID NO: 77

```
5'-ATGGTCAGTGCCTTGGAATATCACACAACCTTTCACCAGCTCTCCCATGATGCAACCCAC
   || |||  | ||  |||| |  ||   |      ||||  ||| |||||||||| || ||
5'-ATAGTCTCTTCCCGGGAACAGGACTTTATGGAGGACCATTTCTGCCATGATGCACCCGAC
```

SEQ ID NO: 78

In the case of the carboxyl terminal portion of the JNK2 isoforms, JNK2/JNK2-a2 shares identity with JNK1-ß2; similarly, JNK2-a1 and JNK2-ß1 have identical carboxy terminal portions. The substantial differences in the amino acid sequences of these isoforms (5 amino acids in JNK2-a2 and JNK2-ß2 are replaced with 47 amino acids in JNK2/JNK2-a2 and JNK2-ß2) result from a slight difference in nucleotide sequence that shifts the reading frame. Specifically, in the ORFs of mRNAs encoding JNK2-a1 and JNK1-ß1, nt 1164-1198 of JNK2-a1 (GenBank accession No. U34821) and nt 1142-1176 of JNK2-ß1 (GenBank accession No. U35002) have the sequence shown below as SEQ ID NO: 79, whereas, in the ORFs of mRNAs encoding JNK2/JNK2-a2 and JNK2-ß2, nt 1178-1207 of JNK2/JNK2-a2 (GenBank accession No. L31951) and nt 1154-1183 of JNK2-ß2 (GenBank accession No. U35003) have the sequence shown below as SEQ ID NO: 80. For purposes of illustration, SEQ ID NOS: 79 and 80 are shown aligned with each other (dashes, "-," indicate bases that are absent in the indicated sequence, and emboldened bases indicate the stop codon for the JNK2-a1 and JNK2-ß1 ORFs):

```
5'-GATCAGCCTTCAGCACAGATGCAGCAGTAAGTAGC        SEQ ID NO: 79
   ||||||||||||||     ||||||||||||||||
5'-GATCAGCCTTCAG-----ATGCAGCAGTAAGTAGC        SEQ ID NO: 80
```

Due to this divergence between the JNK2 isoforms, antisense oligonucleotides derived from the reverse complement of SEQ ID NO: 79 (*i.e.*, SEQ ID NO: 81, see below) are specifically hybridizable to, and may be selected and used to modulate the expression of, mRNAs encoding JNK2-a1 and JNK2-ß1 without significantly effecting the expression of JNK2/JNK2-a2 and JNK2-ß2. In like fashion, antisense oligonucleotides derived from the reverse complement of SEQ ID NO: 80 (*i.e.*, SEQ ID NO: 82, see below) are specifically hybridizable to, and may be selected and used to modulate the expression of, mRNAs encoding JNK2/JNK2-a2 and JNK2-ß2 without significantly effecting the expression of JNK2-a1 and JNK2-ß1. As an example, ISIS 12564 (SEQ ID NO: 35) corresponds to SEQ ID NO: 82 but not to SEQ ID NO: 81, and is thus specifically hybridizable to, and may be used to modulate the expression of, mRNAs encoding JNK2/JNK2-a2 and JNK2-ß2 but not those encoding JNK2-a1 and JNK2-a1:

```
5'-GCTACTTACTGCTGCATCTGTGCTGAAGGCTGATC          SEQ ID NO: 81
   ||||||||||||||||||     ||||||||||||
5'-GCTACTTACTGCTGCAT-----CTGAAGGCTGATC          SEQ ID NO: 82
            |||||||||     ||||||||||||
      5'-CTGCTGCAT-----CTGAAGGCTGA              SEQ ID NO: 35
```

In preferred embodiments, such isoform-specific oligonucleotides such as are described above are methoxyethoxy "gapmers" or "wingmers" in which the RNase H-sensitive "gap" or "wing" is positioned so as to overlap a region of nonidentity in the above antisense sequences, *i.e.*, SEQ ID NOS: 77, 78, 81 and 82.

Example 5: Oligonucleotide-Mediated Inhibition of JNK3 Expression

A. JNK3 oligonucleotide sequences: Table 14 lists the nucleotide sequences of oligonucleotides designed to specifically hybridize to JNK3 mRNAs and the corresponding

ISIS and SEQ ID numbers thereof. The target gene nucleotide co-ordinates and gene target region are also included. The nucleotide co-ordinates are derived from GenBank accession No. U07620, locus name "HSU07620" see also Figure 4(A) of Mohit *et al.*, *Neuron*, **1994**, *14*, 67). The abbreviations for gene target regions are as follows: 5'-UTR, 5' untranslated region; tIR, translation initiation region; ORF, open reading frame; 3'-UTR, 3' untranslated region. It should be noted that the oligonucleotide target co-ordinate positions and gene target regions may vary within mRNAs encoding related isoforms of JNK3 (see subsection D, below).

The nucleotides of the oligonucleotides whose sequences are presented in Table 14 are connected by phosphorothioate linkages and are "gapmers." Specifically, the six nucleotides of the 3' and 5' termini are 2'-methoxyethoxy- modified and are shown emboldened in Table 14, whereas the central eight nucleotides are unmodified at the 2' position (*i.e.*, 2-deoxy).

In addition to hybridizing to human JNK3 mRNAs, the full oligonucleotide sequences of ISIS Nos. 16692, 16693, 16703, 16704, 16705, 16707, and 16708 (SEQ ID NOS: 46, 47, 56, 57, 58, 60 and 61, respectively) specifically hybridize to mRNAs from *Rattus norvegicus* that encode a stress-activated protein kinase named "p54ß" (Kyriakis *et al.*, *Nature*, **1994**, *369*, 156; GenBank accession No. L27128, locus name "RATSAPKC." Furthermore, the full oligonucleotide sequences of 16692, 16693, 16695, 16703, 16704, 16705, 16707 and 16708 (SEQ ID NOS: 46, 47, 49, 56, 57, 58, 60 and 61, respectively) specifically hybridize to mRNAs from *Mus musculus* that encode a mitogen activated protein (MAP) kinase stress activated protein named the "p45$9^{3F12}$ SAP kinase" (Martin *et al.*, *Brain Res. Mol. Brain Res.*, **1996**, *35*, 47; GenBank accession No. L35236, locus name "MUSMAPK"). These oligonucleotides are thus preferred embodiments of the invention for investigating

the role of the p54ß and p459[3F12] SAP protein kinases in rat or mouse, respectively, *in vitro*, *i.e.*, in cultured cells or tissues derived from whole animals or *in vivo*. The target gene nucleotide co-ordinates and gene target regions for these oligonucleotides, as defined for these GenBank entries, are detailed in Table 15.

B. JNK3-specific probes: In initial screenings of a set of oligonucleotides derived from the JNK3 sequence for biological activity, a cDNA clone of JNK3 (Derijard *et al.*, *Cell*, **1994**, *76*, 1025) was radiolabeled and used as a JNK3-specific probe in Northern blots. Alternatively, however, one or more of the oligonucleotides of Table 14 is detectably labeled and used as a JNK3-specific probe.

C. Western Assays: In order to assess the effect of oligonucleotides targeted to *JNK3* mRNAs on JNK3 protein levels, Western assays are performed essentially as described above in Examples 2 through 4. A primary antibody that specifically binds to JNK3 is purchased from, for example, Upstate Biotechnology, Inc. (Lake Placid, NY), StressGen Biotechnologies Corp. (Victoria, BC, Canada), or New England Biolabs, Inc. (Beverly, MA).

TABLE 14

Nucleotide Sequences of JNK3 Oligonucleotides

ISIS NO.	NUCLEOTIDE SEQUENCE[1] (5' -> 3')	SEQ ID NO:	TARGET GENE NUCLEOTIDE CO-ORDINATES	GENE TARGET REGION
16690	**TTC**-**AAC**-AGT-TTC-TT**G**-**CAT**-**AA**	44	0157-0176	5'-UTR
16691	**CTC**-**ATC**-TAT-AGG-AA**A**-**CGG**-**GT**	45	0182-0200	5'-UTR
16692	**TGG**-**AGG**-CTC-ATA-AA**T**-**ACC**-**AC**	46	0215-0234	tIR

ISIS NO.	NUCLEOTIDE SEQUENCE[1] (5' -> 3')	SEQ ID NO:	TARGET GENE NUCLEOTIDE CO-ORDINATES	GENE TARGET REGION
16693	**TAT-AAG**-AAA-TGG-AGG-**CTC-AT**	47	0224-0243	tIR
16694	**TCA-CAT**-CCA-ATG-TTG-**GTT-CA**	48	0253-0272	ORF
16695	**TTA-TCG**-AAT-CCC-TGA-**CAA-AA**	49	0281-0300	ORF
16696	**GTT-TGG**-CAA-TAT-ATG-**ACA-CA**	50	0310-0329	ORF
16697	**CTG-TCA**-AGG-ACA-GCA-**TCA-TA**	51	0467-0486	ORF
16698	**AAT-CAC**-TTG-ACA-TAA-**GTT-GG**	52	0675-0694	ORF
16699	**TAA-ATC**-CCT-GTG-AAT-**AAT-TC**	53	0774-0793	ORF
16700	**GCA-TCC**-CAC-AGA-CCA-**TAT-AT**	54	0957-0976	ORF
16702	**TGT-TCT**-CTT-TCA-TCC-**AAC-TG**	55	1358-1377	ORF
16703	**TCT-CAC**-TGC-TGT-TCA-**CTG-CT**	56	1485-1504	tIR
16704	**GGG-TCT**-GGT-CGG-TGG-**ACA-TG**	57	1542-1561	3'-UTR
16705	**AGG-CTG**-CTG-TCA-GTG-**TCA-GA**	58	1567-1586	3'-UTR
16706	**TCA-CCT**-GCA-ACA-ACC-**CAG-GG**	59	1604-1623	3'-UTR
16707	**GCG-GCT**-AGT-CAC-CTG-**CAA-CA**	60	1612-1631	3'-UTR
16708	**CGC-TGG**-GTT-TCG-CAG-**GCA-GG**	61	1631-1650	3'-UTR
16709	**ATC-ATC**-TCC-TGA-AGA-**ACG-CT**	62	1647-1666	3'-UTR

[1]Emboldened residues are 2'-methoxyethoxy- modified.

TABLE 15
Rat and Mouse Gene Target Locations of JNK3 Oligonucleotides

ISIS NO.	SEQ ID NO:	Rat p54ß NUCLEOTIDE CO-ORDINATES[1]	GENE TARGET REGION	Mouse p459[3F12] NUCLEOTIDE CO-ORDINATES[2]	GENE TARGET REGION
16692	46	0213-0232	5'-UTR	0301-0320	tIR
16693	47	0222-0241	5'-UTR	0310-0329	tIR
16695	49	---	---	0367-0386	ORF
16703	56	1506-1525	ORF	1571-1590	tTR
16704	57	1563-1582	ORF	1628-1647	3'-UTR
16705	58	1588-1607	ORF	1653-1672	3'-UTR
16707	60	1633-1652	tTR	1698-1717	3'-UTR
16708	61	1652-1671	3'-UTR	1717-1736	3'-UTR

[1]Co-ordinates from GenBank Accession No. L27128, locus name "RATSAPKC."

[2]Co-ordinates from GenBank Accession No. L35236, locus name "MUSMAPK."

D. Oligonucleotides specific for JNK3 isoforms: Two isoforms of JNK3 have been described. JNK3-a1 was initially cloned and named "p49[3F12] kinase" by (Mohit *et al. Neuron*, **1995**, *14*, 67). Subsequently, two cDNAs encoding related isoforms of JNK3 were cloned and their nucleotide sequences determined (Gupta *et al.*, *EMBO Journal*, **1996**, *15*, 2760). The isoforms are named JNK3-a1 (GenBank accession No. U34820, locus name "HSU34820") and JNK3-a2 (GenBank accession No. U34819, locus name "HSU34819") herein. The two isoforms of JNK3, which probably arise from alternative mRNA splicing, may each interact with different transcription factors or sets of transcription factors (Gupta *et al.*, *EMBO Journal*, **1996**, *15*, 2760). As detailed below, certain oligonucleotides of the invention are specific for each of these isoforms of JNK3.

JNK3-a1 and JNK-a2 differ at their carboxyl terminal portions. The substantial differences in the amino acid sequences of these isoforms (5 amino acids in JNK3-a1 are replaced with 47 amino acids in JNK3-a2) result from a slight difference in nucleotide sequence that shifts the reading frame. Specifically, in the ORF of mRNAs encoding JNK3-a1, nucleotides (nt) 1325-1362 of JNK3-a1 (GenBank accession No. U34820) have the sequence shown below as SEQ ID NO: 83, whereas, in the ORF of mRNAs encoding JNK3-a2, nt 1301-1333 of JNK3-a2 (GenBank accession No. U34819) have the sequence shown below as SEQ ID NO: 84. For purposes of illustration, SEQ ID NOS: 83 and 202 are shown aligned with each other (vertical marks, "|," indicate bases that are identical in both sequences; dashes, "-," indicate bases that are absent in the indicated sequence; and emboldened bases indicate the stop codon for the JNK3-a1 ORF):

```
5'-GGACAGCCTTCTCCTTCAGCACAGGTGCAGCAGTGAAC      SEQ ID NO: 83
   ||||||||||||||||||     ||||||||||||||
5'-GGACAGCCTTCTCCTTCAG-----GTGCAGCAGTGAAC      SEQ ID NO: 84
```

Due to this divergence between the JNK3 isoforms, antisense oligonucleotides derived from the reverse complement of SEQ ID NO: 83 (*i.e.*, SEQ ID NO: 85, see below) are specifically hybridizable to mRNAs encoding JNK3-a1, and may be selected and used to modulate the expression of JNK3-a1 without significantly effecting the expression of JNK3-a2. In like fashion, antisense oligonucleotides derived from the reverse complement of SEQ ID NO: 84 (*i.e.*, SEQ ID NO: 86, see below) are specifically hybridizable to mRNAs encoding JNK3-a2, and may be selected and used to modulate the expression of JNK3-a2 without significantly effecting the expression of JNK3-a1:

```
5'-GTTCACTGCTGCACCTGTGCTGAAGGAGAAGGCTGTCC      SEQ ID NO: 85
   |||||||||||||||     ||||||||||||||||||
5'-GTTCACTGCTGCAC-----CTGAAGGAGAAGGCTGTCC      SEQ ID NO: 86
```

In preferred embodiments, such isoform-specific oligonucleotides such as are described above are methoxyethoxy "gapmers" or "wingmers" in which the RNase H-sensitive "gap" or "wing" is positioned so as to overlap a region of nonidentity in the above antisense sequences, *i.e.*, SEQ ID NOS: 85 and 86.

E. Activities of JNK3 oligonucleotides: The JNK3-specific phosphorothioate, 2'-methoxyethoxy "gapmer" oligonucleotides (Table 14) were screened for their ability to affect JNK3 mRNA levels in SH-SY5Y cells (Biedler *et al.*, *Cancer Res.*, **1973**, *33*, 2643). SH-SY5Y cells express a variety of mitogen-activated protein kinases (MAPKs; see, e.g., Cheng *et al.*, *J. Biol. Chem.*, **1998**, *273*, 14560). Cells were grown in DMEM essentially as previously described (e.g., Singleton *et al.*, *J. Biol. Chem.*, **1996**, *271*, 31791; Jalava *et al.*, *Cancer Res.*, **1990**, *50*, 3422) and treated with oligonucleotides at a concentration of 200 nM as described in Example 2. Control cultures were treated with an aliquot of LIPOFECTIN™ that contained no oligonucleotide.

The results are shown in Table 16. Oligonucleotides showing levels of inhibition of *JNK3* mRNA levels of at least 45% include ISIS Nos. 16692, 16693, 16694, 16695, 16696, 16697, 16702, 16703, 16704, 16705 and 16706 (SEQ ID NOS:46, 47, 48, 49, 50, 51, 55, 56, 57, 58 and 59, respectively). These oligonucleotides are preferred embodiments of the invention for modulating JNK3 expression. Oligonucleotides inhibiting *JNK3* mRNAs by at least 60% in this assay include ISIS Nos. 16693, 16702, 16703 and 16704 (SEQ ID NOS: 47,55, 56 and 57, respectively). These oligonucleotides are thus more preferred embodiments of the invention for modulating JNK3 expression.

TABLE 16: Activities of JNK3 Oligonucleotides

ISIS No:	SEQ ID NO:	GENE TARGET REGION	% EXPRESSION:	% INHIBITION:
control	---	---	100%	0%
16690	44	5'-UTR	60%	40%
16691	45	5'-UTR	66%	34%
16692	46	tIR	47%	53%
16693	47	tIR	40%	60%
16694	48	ORF	42%	58%
16695	49	ORF	44%	56%
16696	50	ORF	55%	45%
16697	51	ORF	54%	46%
16698	52	ORF	63%	37%
16699	53	ORF	61%	39%
16700	54	ORF	N.D.[2]	N.D.
16702	55	ORF	39%	61%
16703	56	tTR	30%	70%
16704	57	3'-UTR	36%	64%
16705	58	3'-UTR	42%	58%
16706	59	3'-UTR	45%	55%
16707	60	3'-UTR	73%	27%
16708	61	3'-UTR	68%	32%
16709	62	3'-UTR	66%	34%

[1] Cells treated with LIPOFECTIN™ only (no oligonucleotide).

[2] N.D., not determined.

Example 6: Effect of Oligonucleotides Targeted to AP-1 Subunits on Enzymes Involved in Metastasis

Patients having benign tumors, and primary malignant tumors that have been detected early in the course of their development, may often be successfully treated by the surgical

removal of the benign or primary tumor. If unchecked, however, cells from malignant tumors are spread throughout a patient's body through the processes of invasion and metastasis. Invasion refers to the ability of cancer cells to detach from a primary site of attachment and penetrate, *e.g.*, an underlying basement membrane. Metastasis indicates a sequence of events wherein (1) a cancer cell detaches from its extracellular matrices, (2) the detached cancer cell migrates to another portion of the patient's body, often *via* the circulatory system, and (3) attaches to a distal and inappropriate extracellular matrix, thereby created a focus from which a secondary tumor can arise. Normal cells do not possess the ability to invade or metastasize and/or undergo apoptosis (programmed cell death) if such events occur (Ruoslahti, *Sci. Amer.*, **1996**, *275*, 72).

The matrix metalloproteinases (MMPs) are a family of enzymes which have the ability to degrade components of the extracellular matrix (Birkedal-Hansen, *Current Op. Biol.*, **1995**, 7, 728). Many members of the MMP family have been found to have elevated levels of activity in human tumors as well as other disease states (Stetler-Stevenson *et al.*, *Annu. Rev. Cell Biol.*, **1993**, *9*, 541; Bernhard *et al.*, *Proc. Natl. Acad. Sci. (U.S.A.)*, **1994**, *91*, 4293). In particular, one member of this family, matrix metalloproteinase-9 (MMP-9), is often found to be expressed only in tumors and other diseased tissues (Himelstein *et al.*, *Invasion & Metastasis*, **1994**, *14*, 246). Several studies have shown that regulation of the MMP-9 gene may be controlled by the AP-1 transcription factor (Kerr *et al.*, *Science*, **1988**, *242*, 1242; Kerr *et al.*, *Cell*, **1990**, *61*, 267; Gum *et al.*, *J. Biol. Chem.*, **1996**, *271*, 10672; Hua *et al.*, *Cancer Res.*, **1996**, *56*, 5279). In order to determine whether MMP-9 expression can be influenced by AP-1 modulation, the following experiments were conducted on normal human epidermal keratinocytes (NHEKs). Although NHEKs normally express no

detectable MMP-9, MMP-9 can be induced by a number of stimuli, including TPA (12-*O*-tetradecanoylphorbol 13-acetate). ISIS 10582, an oligonucleotide targeted to *c-jun*, was evaluated for its ability to modulate MMP-9 expression (see pending application Serial No. 08/837,201, filed April 14, 1997, attorney docket No. ISPH-0209. The results (Table 16) demonstrate that ISIS 10582 is able to completely inhibit the expression of MMP-9 after induction with TPA.

TABLE 17
Effect of *c-jun* Oligonucleotide on MMP-9 Expression

Treatment	MMP-9
Basal	4
TPA - no oligo	100
10582: *c-jun* active	6
11562: sense control	99
11563: scrambled control	95
11564: mismatch control	89

These results demonstrate that c-Jun is required for TPA-mediated induction of MMP-9, and indicate that oligonucleotides targeted to AP-1 subunits can inhibit the expression of MMP family members, thereby modulating the ability of cancer cells to invade other tissues and/or metastasize to other sites in a patient's body. Because JNK proteins activate AP-1 by phosphorylating the N-terminal portion of the Jun subunit thereof, modulation of one or more JNK proteins by the oligonucleotides of the present disclosure will also modulate the expression of MMP family members and limit the metastatic ability of cancer cells.

Example 7: Treatment of Human Tumors in Mice with Oligonucleotides Targeted to JNK Proteins

Approximately 5 x 10^6 breast adenocarcinoma cells (cell line MDA-MB-231; American Type Culture Collection, Richmond, VA, No. ATCC HTB-26) were implanted subcutaneously in the right inner thigh of nude mice (n=6 for each of three sets of mice). Oligonucleotides ISIS 15346 (JNK1, SEQ ID NO:16) and 15353 (JNK2, SEQ ID NO:31) were suspended in saline and administered once daily to two sets of mice on the first day the tumor volume was about 100 mm^3. A saline-only (0.9% NaCl) solution was given to a third set of animals as a control. Oligonucleotides were given by intravenous injection at a dosage of 25 mg/kg. Tumor size was measured and tumor volume was calculated on days 12, 19, 26 and 33 following tumor cell inoculation.

The results are shown in Table 18. Both 15346 (JNK1, SEQ ID NO:16) and 15353 (JNK2, SEQ ID NO:31) inhibited tumor growth compared to the saline control. Specifically, on days 26 and 33, the MDA-MB-231 tumors in animals that had been treated with the oligonucleotides had smaller volumes than the tumors in saline-treated animals, indicating that the oligonucleotides inhibited the growth of the tumors.

The antisense compounds of the invention are also tested for their ability to slow or eliminate the growth of xenografts resulting from, for example, human cervical epithelial carcinoma cells (HeLa cell line, ATCC No. ATCC CCL-2), human lung carcinoma cells (cell line A549, ATCC No. ATCC CCL-185), human adenocarcinoma cells (cell line SW480, ATCC No. ATCC CCL-228), human bladder carcinoma cells (cell line T24, ATCC No. HTB-4), human pancreatic carcinoma cells (cell line MIA PaCa, ATCC No. CRL-1420) and human small cell carcinoma cells (cell line NCI-H69, ATCC HTB-119). Xenografts resulting from these and other cell lines are established using essentially the same techniques as were used for the experiments using MDA-MB 231 cells.

TABLE 18: Response of MDA-MB-231 Tumors in Mice to Oligonucleotides Targeted to JNK1 and JNK2

Treatment:	Mean Tumor Volume (cm^3)	Standard Deviation	Standard Error
Saline:			
Day 12	0.122	0.053	0.022
Day 19	0.253	0.078	0.032
Day 26	0.648	0.265	0.108
Day 33	1.560	0.887	0.362
ISIS (JNK1):			
Day 12	0.122	0.033	0.014
Day 19	0.255	0.099	0.040
Day 26	0.400	0.202	0.083
Day 33	0.638	0.416	0.170
ISIS (JNK2):			
Day 12	0.122	0.041	0.017
Day 19	0.230	0.072	0.029
Day 26	0.358	0.131	0.053
Day 33	0.762	0.366	0.150

Example 8: Oligonucleotides Targeted to Genes Encoding Rat JNK Proteins

In order to study the role of JNK proteins in animal models, oligonucleotides targeted to the genes encoding JNK1, JNK2 and JNK3 of *Rattus norvegicus* were prepared. These oligonucleotides are 2'-methoxyethoxy, phosphodiester / 2'-hydroxyl, phosphorothioate / 2'-methoxyethoxy, phosphodiester "gapmers" in which every cytosine residue is 5-methylcytosine (m5c). These antisense compounds were synthesized according to the methods of the disclosure. Certain of these

oligonucleotides are additionally specifically hybridizable to JNK genes from other species as indicated herein. The oligonucleotides described in this Example were tested for their ability to modulate rat JNK mRNA levels essentially according to the methods described in the preceding Examples, with the exceptions that the cell line used was rat A10 aortic smooth muscle cells (ATCC No. ATCC CRL-1476) and the probes used were specific for rat JNK1, JNK2 or JNK3 (see *infra*). A10 cells were grown and treated with oligonucleotides essentially as described by (Cioffi *et al. Mol. Pharmacol.*, **1997**, *51*, 383).

A. JNK1: Table 19 describes the sequences and structures of a set of oligonucleotides, ISIS Nos. 21857 to 21870 (SEQ ID NOS:111 to 124, respectively) that were designed to be specifically hybridizable to nucleic acids from *Rattus norvegicus* that encode a stress-activated protein kinase named "p54?" or "SAPK?" that is homologous to the human protein JNK1 (Kyriakis *et al.*, *Nature*, **1994**, *369*, 156; GenBank accession No. L27129, locus name "RATSAPKD"). In Table 19, emboldened residues are 2'-methoxyethoxy-residues (others are 2'-deoxy-); "**C**" residues are 2'-methoxyethoxy-5-methyl-cytosines and "C" residues are 5-methyl-cytosines; "o" indicates a phosphodiester linkage; and "s" indicates a phosphorothioate linkage. The target gene co-ordinates are from GenBank Accession No. L27129, locus name "RATSAPKD."

TABLE 19:

Nucleotide Sequences of Rat JNK1 Oligonucleotides

ISIS NO.	NUCLEOTIDE SEQUENCE (5' -> 3')	SEQ ID NO	TARGET GENE NUCLEOTIDE COORD	GENE TARGET REGION
21857	CoAoAoCoGsTsCsCsCsGsCsGsCsTsCsGoGoCoCoG	111	0002-0021	5'-UTR
21858	CoCoToGoCsTsCsGsCsGsGsCsTsCsCsGoCoGoToT	112	0029-0048	5'-UTR
21859	CoToCoAoTsGsAsTsGsGsCsAsAsGsCsAoAoToToA	113	0161-0180	tIR
21860	ToGoToToGsTsCsAsCsGsTsTsTsAsCsToToCoToG	114	0181-0200	ORF
21861	CoGoGoToAsGsGsCsTsCsGsCsTsTsAsGoCoAoToG	115	0371-0390	ORF
21862	CoToAoGoGsGsAsTsTsTsCsTsGsTsGsGoToGoToG	116	0451-0470	ORF
21863	CoAoGoCoAsGsAsGsTsGsAsAsGsGsTsGoCoToToG	117	0592-0611	ORF
21864	ToCoGoToTsCsCsTsGsCsAsGsTsCsCsToToGoCoC	118	0691-0710	ORF
21865	CoCoAoToTsTsCsTsCsCsCsAsTsAsAsToGoCoAoC	119	0811-0830	ORF
21866	ToGoAoAoTsTsCsAsGsGsAsCsAsAsGsGoToGoToT	120	0901-0920	ORF
21867	AoGoCoToTsCsGsTsCsTsAsCsGsGsAsGoAoToCoC	121	1101-1120	ORF
21868	CoAoCoToCsCsTsCsTsAsTsTsGsTsGsToGoCoToC	122	1211-1230	ORF
21869	GoCoToGoCsAsCsCsTsAsAsAsGsGsAsGoAoCoGoG	123	1301-1320	ORF
21870	CoCoAoGoAsGsTsCsGsGsAsTsCsTsGsToGoGoAoC	124	1381-1400	ORF

These antisense compounds were tested for their ability to modulate levels of p54? (JNK1) and p54a (JNK2) mRNA in A10 cells via Northern assays. Due to the high degree of sequence identity between the human and rat genes, radiolabeled human JNK1 (Example 3) and JNK2 (Example 4) cDNAs functioned as specific probes for the rat homologs.

The results are shown in Table 20. ISIS Nos. 21857 to 21870 (SEQ ID NOS:111 to 124, respectively) showed 70% to 90% inhibition of rat JNK1 mRNA levels. These oligonucleotides are preferred embodiments of the invention for modulating rat JNK1 expression. Oligonucleotides showing levels of inhibition of at least 90% in this assay include ISIS Nos. 21858, 21859, 21860, 21861, 21862, 21864, 21865, 21866 and 21867 (SEQ ID NOS:112, 113, 114, 115, 116, 118, 119, 120 and 121, respectively). These oligonucleotides are thus more preferred embodiments of the invention for modulating rat JNK1 expression. ISIS 21859 (SEQ ID NO:113) was chosen for use in further studies (*infra*).

Two of the oligonucleotides, ISIS Nos. 21861 and 21867 (SEQ ID NOS:115 and 121, respectively) demonstrated a capacity to modulate both JNK1 and JNK2. Such oligonucleotides are referred to herein as "Pan JNK" antisense compounds because the term "Pan" is used in immunological literature to refer to an antibody that recognizes, e.g., all isoforms of a protein or subtypes of a cell type. The Pan JNK oligonucleotides are discussed in more detail *infra*.

In addition to being specifically hybridizable to nucleic acids encoding rat JNK1, some of the oligonucleotides described in Table R-1 are also specifically hybridizable with JNK1-encoding nucleic acids from other species. ISIS 21859 (SEQ ID NO:113) is complementary to bases 4 to 23 of cDNAs encoding human JNK1a1 and JNK1ß1 (i.e., GenBank accession Nos. L26318 and U35004, respectively). ISIS 21862 (SEQ ID NO:116) is complementary to bases 294 to 313 of the human JNK1a1 and JNK1ß1 cDNAs (GenBank accession Nos. L26318 and U35004,

respectively), bases 289 to 308 of the human JNK1ß2 cDNA (GenBank accession No. U35005), and bases 288 to 307 of the human JNK1a2 cDNA (GenBank accession No. U34822). Finally, ISIS 21865 is complementary to bases 654 to 673 of the human JNK1a1 cDNA (GenBank accession No. L26318) and to bases 648 to 667 of the human JNK1a2 cDNA (GenBank accession No. U34822). These oligonucleotides are tested for their ability to modulate mRNA levels of human JNK1 genes according to the methods described in Example 3.

TABLE 20: Activities of Oligonucleotides Targeted to Rat JNK1

ISIS No:	SEQ ID NO:	GENE TARGET REGION	% EXPRESSION JNK1	% EXPRESSION JNK2
control [1]	---	---	100%	100%
21857	111	5'-UTR	24%	91%
21858	112	5'-UTR	8%	89%
21859	113	tIR	5%	106%
21860	114	ORF	8%	98%
21861	115	ORF	6%	13%
21862	116	ORF	6%	133%
21863	117	ORF	24%	107%
21864	118	ORF	8%	106%
21865	119	ORF	5%	50%
21866	120	ORF	8%	98%
21867	121	ORF	5%	21%
21868	122	ORF	15%	112%
21869	123	ORF	30%	93%
21870	124	ORF	11%	87%

[1] Cells treated with LIPOFECTIN™ only (no oligonucleotide).

B. JNK2: Table 21 describes the sequences and structures of a set of oligonucleotides, ISIS Nos. 18254 to 18267 (SEQ ID NOS:125 to 138, respectively) that were designed to be specifically hybridizable to nucleic acids that encode a stress-activated protein kinase from *Rattus norvegicus* that encode a stress-activated protein kinase named "p54a" or "SAPKa" (Kyriakis *et al.*, *Nature*, **1994**, *369*, 156). The structures of three control oligonucleotides, ISIS Nos. 21914 to 21916 (SEQ ID NOS:139 to 141, respectively) are also shown in the table. Two isoforms of p54a have been described: "p54a1" (GenBank accession No. L27112, locus name "RATSAPKA") and "p54a2" (GenBank accession No. L27111, locus name "RATSAPKB"). With the exception of ISIS 18257 (SEQ ID NO:128), the oligonucleotides described in Table 21 are specifically hybridizable to nucleic acids encoding either p54a1 or p54a2. ISIS 18257 is specifically hybridizable to nucleic acids encoding p54a2 (i.e., GenBank accession No. L27112, locus name "RATSAPKB"). In Table 21, emboldened residues are 2'-methoxyethoxy-residues (others are 2'-deoxy-); "**C**" residues are 2'-methoxyethoxy-5-methyl-cytosines and "C" residues are 5-methyl-cytosines; "o" indicates a phosphodiester linkage; and "s" indicates a phosphorothioate linkage. The target gene co-ordinates are from GenBank Accession No. L27112, locus name "RATSAPKB."

TABLE 21: Nucleotide Sequences of Rat JNK2 Oligonucleotides

ISIS NO.	NUCLEOTIDE SEQUENCE (5' -> 3')	SEQ ID NO:	TARGET GENE NUCLEOTIDE CO-ORDINATES	GENE TARGET REGION
18254	ToCoAoToGsAsTsGsTsAsGsTsGsTsCsAoToAoCoA	125	0001-0020	tIR
18255	ToGoToGoGsTsGsTsGsAsAsCsAsCsAsToToToAoA	126	0281-0300	ORF
18256	CoCoAoToAsTsGsAsAsTsAsAsCsCsTsGoAoCoAoT	127	0361-0380	ORF
18257	GoAoToAoTsCsAsAsCsAsTsTsCsTsCsCoToToGoT	128	0621-0640	ORF
18258	GoCoToToCsGsTsCsCsAsCsAsGsAsGsAoToCoCoG	129	0941-0960	ORF
18259	GoCoToCoAsGsTsGsGsAsCsAsTsGsGsAoToGoAoG	130	1201-1220	ORF
18260	AoToCoToGsCsGsAsGsGsTsTsTsCsAsToCoGoGoC	131	1281-1300	tTR
18261	CoCoAoCoCsAsGsCsTsCsCsCsAsTsGsToGoCoToC	132	1341-1360	3'-UTR
18262	CoAoGoToTsAsCsAsCsAsTsGsAsTsCsToGoToCoA	133	1571-1590	3'-UTR
18263	AoAoGoAoGsGsAsTsTsAsAsGsAsGsAsToToAoToT	134	1701-1720	3'-UTR
18264	AoGoCoAoGsAsGsTsGsAsAsAsTsAsCsAoAoCoToT	135	2001-2020	3'-UTR
18265	ToGoToCoAsGsCsTsCsTsAsCsAsTsTsAoGoGoCoA	136	2171-2190	3'-UTR
18266	AoGoToAoAsGsCsCsCsGsGsTsCsTsCsCoToAoAoG	137	2371-2390	3'-UTR

18267	**A**o**A**o**A**o**T**o**G**sGsAsAsAsGsGsAsCsAs**G**o**C**o**A**o**G**o**C**	138	2405-2424	3'-UTR
21914	**G**o**C**o**T**o**C**o**A**sGsTsGsGsAsTsAsTsGsGs**A**o**T**o**G**o**A**o**G**	139	18259 control	---
21915	**G**o**C**o**T**o**A**o**A**sGsCsGsGsTsCsAsAsGsGs**T**o**T**o**G**o**A**o**G**	140	18259 control	---
21916	**G**o**C**o**T**o**C**o**G**sGsTsGsGsAsAsAsTsGsGs**A**o**T**o**C**o**A**o**G**	141	18259 control	---

TABLE 22:

Activities of Oligonucleotides Targeted to Rat JNK2

ISIS No:	SEQ ID NO:	GENE TARGET REGION	% EXPRESSION	% INHIBITION
control[1]	---	---	100%	0%
18254	125	tIR	20%	80%
18255	126	ORF	21%	79%
18256	127	ORF	80%	20%
18257	128	ORF	32%	68%
18258	129	ORF	19%	81%
18259	130	ORF	15%	85%
18260	131	ORF	41%	59%
18261	132	3'-UTR	47%	53%
18262	133	3'-UTR	50%	50%
18263	134	3'-UTR	63%	37%
18264	135	3'-UTR	48%	52%
18265	136	3'-UTR	38%	62%
18266	137	3'-UTR	66%	34%
18267	138	3'-UTR	84%	16%

[1] Cells treated with LIPOFECTIN™ only (no oligonucleotide).

These antisense compounds were tested for their ability to modulate levels of p54a (JNK2) mRNA in A10 cells using the radiolabeled human JNK2 cDNA as a probe as described *supra*. The results are shown in Table 22. Oligonucleotides showing levels of inhibition from ≥ about 60% to about 100% of rat JNK2 mRNA levels include ISIS Nos. 18254, 18255, 18257, 18258, 18259, 18260 and 18265 (SEQ ID NOS:125, 126, 128, 129, 130, 131 and 136, respectively). These oligonucleotides are preferred embodiments of the invention for modulating rat JNK2

expression. Oligonucleotides showing levels of inhibition of rat JNK1 mRNAs by at least 80% in this assay include ISIS Nos. 18254, 18255, 18258 and 18259 (SEQ ID NOS:125, 126, 129 and 130, respectively). These oligonucleotides are thus more preferred embodiments of the invention for modulating rat JNK2 expression. ISIS 18259 (SEQ ID NO:130) was chosen for use in further studies (*infra*).

C. Dose Response: A dose response study was conducted using oligonucleotides targeted to rat JNK1 (ISIS 21859; SEQ ID NO:113) and JNK2 (ISIS 18259; SEQ ID NO:130) and Northern assays. The results (Table 23) demonstrate an increasing effect as the oligonucleotide concentration is raised and confirm that ISIS Nos. 21859 and 18259 (SEQ ID NOS:113 and 130, respectively) specifically modulate levels of mRNA encoding JNK1 and JNK2, respectively.

TABLE 23:

Dose-Dependent Response to Rat JNK Antisense Oligonucleotides (ASOs)

ISIS #	SEQ ID NO:	ASO Description	Dose	% EXPRESSION JNK1	% EXPRESSION JNK2
		active ASO	10 nM	74	101
			50 nM	25	98
			100 nM	11	99
			200 nM	8	101
18259	130	rat JNK2	0 nM	100	100
		active ASO	10 nM	95	81
			50 nM	101	35
			100 nM	94	15
			200 nM	89	5

D. JNK3: Table 24 describes the sequences and structures of a set of oligonucleotides, ISIS Nos. 21899 to 21912 (SEQ ID NOS:142 to 155, respectively) that were designed to be specifically hybridizable to nucleic acids from *Rattus norvegicus* that encode a stress-activated protein kinase named "p54ß" that is homologous to the human protein JNK3 (Kyriakis *et al.*, *Nature*, **1994**, *369*, 156; GenBank accession No. L27128, locus name "RATSAPKC"). In Table 24, emboldened residues are 2'-methoxyethoxy-residues (others are 2'-deoxy-); "**C**" residues are 2'-methoxyethoxy-5-methyl-cytosines and "C" residues are 5-methyl-cytosines; "o" indicates a phosphodiester linkage; and "s" indicates a phosphorothioate linkage. The target gene co-ordinates are from GenBank Accession No. L27128, locus name "RATSAPKC." The oligonucleotides are tested for their ability to modulate rat JNK3 mRNA levels essentially according to the methods described in the preceding Examples.

In addition to being specifically hybridizable to nucleic acids encoding rat JNK3, some of the oligonucleotides described in Table 24 are also specifically hybridizable with JNK3-encoding nucleic acids from humans and *Mus musculus* (mouse). Table 25 sets out these relationships. These oligonucleotides are tested for their ability to modulate mRNA levels of the human JNK genes according to the methods described in Example 5.

TABLE 24: Nucleotide Sequences of Rat JNK3 Oligonucleotides

ISIS NO.	NUCLEOTIDE SEQUENCE (5' -> 3')	SEQ ID NO:	TARGET GENE NUCLEOTIDE CO-ORDINATES	GENE TARGET REGION
21899	GoGoGoCoTsTsTsCsAsTsTsAsGsCsCsAoCoAoToT	142	0021-0040	5'-UTR
21900	GoGoToToGsGsTsTsCsAsCsTsGsCsAsGoToAoGoT	143	0241-0260	5'-UTR
21901	ToGoCoToCsAsTsGsTsTsGsTsAsAsTsGoToToToG	144	0351-0370	tIR
21902	GoToCoGoAsGsGsAsCsAsGsCsGsTsCsAoToAoCoG	145	0491-0510	ORF
21903	CoGoAoCoAsTsCsCsGsCsTsCsGsTsGsGoToCoCoA	146	0731-0750	ORF
21904	AoCoAoToAsCsGsGsAsGsTsCsAsTsCsAoToGoAoA	147	0901-0920	ORF
21905	GoCoAoAoTsTsTsCsTsTsCsAsTsGsAsAoToToCoT	148	1101-1120	ORF
21906	ToCoGoToAsCsCsAsAsAsCsGsTsTsGsAoToGoToA	149	1321-1340	ORF
21907	CoGoCoCoGsAsGsGsCsTsTsCsCsAsGsGoCoToGoC	150	1601-1620	ORF
21908	GoGoCoToAsGsTsCsAsCsCsTsGsCsAsAoCoAoAoC	151	1631-1650	tTR
21909	GoCoGoToGsCsGsTsGsCsGsTsGsCsTsToGoCoGoT	152	1771-1790	3'-UTR
21910	GoCoToCoAsGsCsTsGsCsGsAsTsAsCsAoGoAoAoC	153	1891-1910	3'-UTR
21911	AoGoCoGoCsGsAsCsTsAsGsAsAsGsTsToAoAoGoT	154	1921-1940	3'-UTR
21912	AoGoGoGoAsGsAsCsCsAsAsAsGsTsCsGoAoGoCoG	155	1941-1960	3'-UTR

TABLE 25: Cross-Hybridizations of Rat JNK3 Oligonucleotides

		Hybridizes	*to:*	
ISIS NO.	**SEQ ID NO:**	**Human JNK3a1[1]**	**Human JNK3a2[2]**	**Mouse JNK3[3]**
21900	143	---	---	bp 329-348
21901	144	bp 193-212	bp 169-188	bp 411-430
21904	147	---	---	bp 961-980
21905	148	bp 943-962	bp 919-938	---
21906	149	---	---	bp 1381-1400
21908	151	bp 1478-1497	bp 1449-1468	bp 1696-1715

[1] GenBank accession No. U34820, locus name "HSU34820" (see also Mohit *et al.*, *Neuron*, **1995**, *14*, 67 and Gupta *et al.*, *EMBO Journal*, **1996**, *15*, 2760).

[2] GenBank accession No. U34819, locus name "HSU34819" (see also Gupta *et al.*, *EMBO Journal*, **1996**, *15*, 2760).

[3] Also known as $p459^{3F12}$ MAPK; GenBank accession No. L35236, locus name "MUSMAPK" (see also Martin *et al.*, *Brain Res. Mol. Brain Res.*, **1996**, *35*, 47).

E. Pan JNK Oligonucleotides: Certain of the oligonucleotides of the invention are capable of modulating two or more JNK proteins and are referred to herein as "Pan JNK" oligonucleotides. For example, ISIS Nos. Nos. 21861 and 21867 (SEQ ID NOS:115 and 121, respectively) demonstrated a capacity to modulate both JNK1 and JNK2 (Table 20). Such

oligonucleotides are useful when the concomitant modulation of several JNK proteins is desired.

Human Pan JNK oligonucleotides are described in Table 26. These oligonucleotides are designed to be complementary to sequences that are identically conserved in (i.e., SEQ ID NOS:156, 158, 159, 160 and 161), or which occur with no more than a one-base mismatch (SEQ ID NO:157), in nucleic acids encoding human JNK1a1, JNK1a2, JNK2a1 and JNK2a2. The oligonucleotides described in Table 26 are evaluated for their ability to modulate JNK1 and JNK2 mRNA levels in A549 cells using the methods and assays described in Examples 3 and 4.

In instances where such common sequences encompass one or more base differences between the JNK genes that it is desired to modulate, hypoxanthine (inosine) may be incorporated at the positions of the oligonucleotide corresponding to such base differences. ("Hypoxanthine" is the art-accepted term for the base that corresponds to the nucleoside inosine; however, the term "inosine" is used herein in accordance with U.S. and PCT rules regarding nucleotide sequences.) As is known in the art, inosine (I) is capable of hydrogen bonding with a variety of nucleobases and thus serves as a "universal" base for hybridization purposes. For example, an oligonucleotide having a sequence that is a derivative of SEQ ID NO:157 having one inosine substitution (TAGGAIATTCTTTCATGATC, SEQ ID NO:162) is predicted to bind to nucleic acids encoding human JNK1a1, JNK1a2, JNK2a1 and JNK2a2 with no mismatched bases. As another example, an oligonucleotide having a sequence that is a derivative of SEQ ID NO:161 having one inosine substitution (GGTTGCAITTTCTTCATGAA, SEQ ID NO:163) is predicted to bind with no mismatched bases to nucleic acids encoding human JNK3a1 and JNK3a2 in addition to JNK1a1, JNK1a2, JNK2a1 and JNK2a2. Such oligonucleotides are evaluated for their ability to modulate JNK1 and JNK2 mRNA levels in A549 cells, and JNK3

mRNA levels in SH-SY5Y cells, using the methods and assays described in Examples 3, 4 and 5.

TABLE 26

Human Pan JNK Oligonucleotides

NUCLEOTIDE SEQUENCE (5' -> 3') AND CHEMICAL MODIFICATIONS*	SEQ ID NO:
$\mathbf{A}^{S}C^{S}\mathbf{A}^{S}\mathbf{T}^{S}C^{S}\mathbf{T}^{S}T^{O}G^{O}A^{O}A^{O}A^{O}T^{O}T^{O}C^{S}\mathbf{T}^{S}\mathbf{T}^{S}C^{S}\mathbf{T}^{S}\mathbf{A}^{S}\mathbf{G}$	156
$\mathbf{T}^{S}\mathbf{A}^{S}\mathbf{G}^{S}\mathbf{G}^{S}\mathbf{A}^{S}\mathbf{T}^{S}A^{O}T^{O}T^{O}C^{O}T^{O}T^{O}T^{O}C^{S}\mathbf{A}^{S}\mathbf{T}^{S}\mathbf{G}^{S}\mathbf{A}^{S}\mathbf{T}^{S}\mathbf{C}$	157
$\mathbf{A}^{S}\mathbf{G}^{S}\mathbf{A}^{S}\mathbf{A}^{S}\mathbf{G}^{S}\mathbf{G}^{S}T^{O}A^{O}G^{O}G^{O}A^{O}C^{O}A^{O}T^{S}\mathbf{T}^{S}C^{S}\mathbf{T}^{S}\mathbf{T}^{S}\mathbf{T}^{S}C$	158
$\mathbf{T}^{S}\mathbf{T}^{S}\mathbf{T}^{S}\mathbf{A}^{S}\mathbf{T}^{S}\mathbf{T}^{S}C^{O}C^{O}A^{O}C^{O}T^{O}G^{O}A^{O}T^{S}C^{S}\mathbf{A}^{S}\mathbf{A}^{S}\mathbf{T}^{S}\mathbf{A}^{S}\mathbf{T}$	159
$\mathbf{T}^{S}C^{S}\mathbf{A}^{S}\mathbf{A}^{S}\mathbf{T}^{S}\mathbf{A}^{S}A^{O}C^{O}T^{O}T^{O}T^{O}A^{O}T^{O}T^{S}C^{S}C^{S}\mathbf{A}^{S}C^{S}\mathbf{T}^{S}\mathbf{G}$	160
$\mathbf{G}^{S}\mathbf{G}^{S}\mathbf{T}^{S}\mathbf{T}^{S}\mathbf{G}^{S}C^{S}\mathbf{A}^{S}G^{O}T^{O}T^{O}T^{O}C^{O}T^{O}T^{S}C^{S}\mathbf{A}^{S}\mathbf{T}^{S}\mathbf{G}^{S}\mathbf{A}^{S}\mathbf{A}$	161

*Emboldened residues, 2'-methoxyethoxy- residues (others are 2'-deoxy-); all "C" residues are 5-methyl-cytosines; "^{O}", phosphodiester linkage; "^{S}", phosphorothioate linkage.

Example 9: Effect of Oligonucleotides Targeted to Human JNK1 and JNK2 on TNFa-induced JNK Activity

Human umbilical vein endothelial cells (HUVEC, Clonetics, San Diego CA) were incubated with oligonucleotide with LipofectinJ in Opti-MEMJ for 4 hours at 371C /5% CO_2. The medium was then replaced with 1% FBS/EGM (Clonetics, Walkersville MD) and incubated for 24 hours at 371C /5% CO_2. Cells were treated with 5 ng/ml TNFa for 15 minutes before lysis. JNK activity was determined by incubating lysates (normalized for protein) with immobilized GST-c-Jun fusion protein (e.g., New England Biolabs, Beverly, MA) + ?^{32}P-ATP. GST-c-Jun beads were washed and SDS-PAGE sample buffer was added. Samples were resolved

by SDS-PAGE and phosphorylated c-Jun was visualized using a Molecular Dynamics PhosphorImager.

Compared to a control oligonucleotide, the JNK1 oligonucleotide ISIS 15346 (SEQ ID NO: 16; 100 nM concentration) inhibited TNFa-induced JNK activity by approximately 70%. The JNK2 oligonucleotide ISIS 15353 (SEQ ID NO: 31; 100 nM) inhibited TNFa-induced JNK activity by approximately 55%. A combination of 50 nM each oligonucleotide inhibited TNFa-induced JNK activity by approximately 68% and a combination of 100 nM each oligonucleotide inhibited TNFa-induced JNK activity by approximately 83%.

Example 10: Effect of Oligonucleotides Targeted to Human JNK1 and JNK2 on Apoptosis

TNFa causes apoptosis in many cell types. The effect of JNK1 or JNK2 antisense oligonucleotides on TNFa-induced apoptosis in HUVEC was examined. HUVEC were incubated with oligonucleotides in Opti-MEMJ plus LipofectinJ for four hours at 371C /5% CO_2. The medium was then replaced with 1% FBS/EGM (Clonetics, Walkersville MD) and incubated for 44 hours at 371C /5% CO_2. Cells were treated with 10 ng/ml TNFa with or without 10 μg/ml cyclohexamide or 100 mM z-VAD.fmk (a caspase inhibitor; Calbiochem , La Jolla CA) and incubated for 24 hours at 371C /5% CO_2. Cells were collected using trypsin/EDTA, washed and fixed in 70% ethanol. Cells were stained with propidium iodide and analyzed for DNA content by flow cytometry. Results are shown in Table 27, expressed as percent hypodiploid cells, a measure of apoptosis. Control oligonucleotides are: ISIS 18076 (CTTTCCGTTGGACCCCTGGG; SEQ ID NO:164), scrambled control for ISIS 15346. ISIS 18078 (GTGCGCGCGAGCCCGAAATC; SEQ ID NO:165), scrambled control for ISIS 15353. Both are 2'-methoxyethoxy gapmers with phosphorothioate backbone linkages throughout.

Table 27

Effect of antisense inhibitors of JNK1 and JNK2 on apoptosis

Numbers given are percent hypodiploid cells (a measure of apoptosis)

	No oligo	JNK1 AS (ISIS 15346)	JNK1 control (ISIS 18076)	JNK2 AS (ISIS 15353)	JNK2 control (ISIS 18078)
Oligo alone	14	13	8	23	11
Oligo + TNFa	15	14	10	32	11
Oligo + Cyclohexamide	7	8	11	27	12
Oligo + z-VAD.fmk	5	5	10	17	9

It can be seen from the table that antisense suppression of JNK1 or JNK2 expression had little effect on resistance to TNFa-induced apoptosis. However, it was found that antisense inhibition of JNK2, but not JNK1, resulted in increased cell death even in the absence of TNFa, suggesting that JNK2 may play a role in protecting these cells from apoptosis. JNK2 oligonucleotide-induced cell death was decreased by the caspase inhibitor z-FAD.fmk, suggesting that caspase activation was involved in this apoptotic response. Protein synthesis was not believed to be required because cyclohexamide, an inhibitor of protein synthesis, had no effect on apoptosis after JNK2 oligonucleotide treatment.

Example 11: Effect of Oligonucleotides Targeted to Human JNK2 on Prostate Cancer

Human JNK2 antisense oligonucleotides were used in a human tumor xenograft model to determine the effectiveness of treating prostate cancer. In advanced prostate cancer,

progression to androgen independence occurs. JNK activation of AP-1 can modulate expression of the androgen receptor.

LNCaP cells (human prostate cancer cells purchased from American Type Culture Collection, Rockville, MD) were maintained in RPMI 1640 (Terry Fox Laboratory, Vancouver, BC, Canada) with 5% fetal bovine serum (GIBCO, Burlington, ON, Canada). Six to eight week old male athymic nude mice (BALB/c strain) were purchased from Harlan Sprague Dawley, Inc. (Indianapolis, IN).

1×10^6 LNCaP cells were inoculated subcutaneously with 0.1 ml MATRIGEL (Becton Dickinson Labware, Bedford, MA) in the flank region of the mice. Blood samples were obtained with tail vein incisions of mice and serum PSA levels were determined by an enzymatic immunoassay kit (Abbott IMX, Montreal, PQ, Canada) according to the manufacturer's protocol. When serum PSA levels increased to around 100 ng/ml, 4-6 weeks post-injection, mice were castrated via a scrotal approach. Mice were treated with 12.5 mg/kg oligonucleotide intraperitoneally once daily, beginning one day after castration. Tumor volume and serum PSA levels were measured once weekly.

Results are shown in Table 28. LNCaP tumor growth rates were 2.5 fold higher in the control group compared to JNK2 antisense group. Tumor volume in the control group increased twofold above baseline by 7 weeks post-castration, and 5-fold by 10 weeks post-castration. In contrast, mean tumor volume in the JNK2 antisense-treated group decreased after castration to 60% of baseline by 4 weeks post-castration and returned to pre-castration level by 7 weeks post-castration. Thereafter, mean tumor volume increased to twofold above baseline by 10 weeks post-castration compared to 5-fold in the control oligonucleotide-treated group.

Differences in serum PSA between the JNK2 antisense-treated mice and control oligonucleotide-treated mice were clear. By one week post-castration, serum PSA decreased by 67%

and 89% in the control oligonucleotide and JNK2 antisense oligonucleotide-treated groups, respectively to nadir levels by one week post-castration. In the control oligonucleotide treated group, mean serum PSA increased beginning two weeks post-castration and returned to pre-castration level by 5 weeks post-castration, a response typical of castrated control mice. Sato et al., *J. Steroid Biochem. Molec. Biol.*, **1996,** *58,* 139-146. By ten weeks post-castration, mean serum PSA increased to threefold above baseline levels. In contrast, in JNK2 antisense treated mice, mean serum PSA remained at or below baseline levels at 10 weeks post-castration.

Time to progression to androgen-independent PSA regulation was defined as the duration of time after castration for serum PSA levels to return to levels equal to or greater than pre-castration levels. Data points were expressed as average PSA levels ± standard error of the mean based on seven measurements. The time to progression to androgen independence after castration was delayed in the mice treated with JNK2 antisense by 100% (10 weeks vs. 5 weeks for control group). No significant toxicity was observed in any treatment group during the 10 week treatment period.

TABLE 28:
JNK2 Antisense Oligonucleotides in Prostate Cancer

ISIS #	SEQ ID NO:	Gene Target	Weeks Post-castration	Tumor volume (mm^3)	Serum PSA levels (ng/ml) 9
15353	31	JNK2	0	203	84
"	"	"	1	149	9
"	"	"	2	119	11
"	"	"	3	128	10
"	"	"	4	118	15
"	"	"	5	159	20

"	"	"	6	166	25
"	"	"	7	196	34
"	"	"	8	239	47
"	"	"	9	307	63
"	"	"	10	422	87
14616		control	0	228	82
"	"	"	1	177	27
"	"	"	2	235	33
"	"	"	3	207	51
"	"	"	4	261	77
"	"	"	5	274	85
"	"	"	6	316	113
"	"	"	7	453	129
"	"	"	8	514	154
"	"	"	9	699	210
"	"	"	10	1020	257

Example 12: Inhibition of inflammatory responses by antisense oligonucleotides targeting JNK family members

JNKs have been implicated as key mediators of a variety of cellular responses and pathologies. JNKs can be activated by environmental stress, such as radiation, heat shock, osmotic shock, or growth factor withdrawal as well as by pro-inflammatory cytokines.

Antisense oligonucleotides targeting any of the JNK family members described in Examples 3-5 are synthesized and purified as in Example 1 and evaluated for their activity in inhibiting inflammatory responses. Such inhibition is evident in the reduction of production of pro-inflammatory molecules by inflammatory cells or upon the attenuation of proliferation of infiltrating or inflammatory cells, the most prominent of which are lymphocytes, neutrophils, macrophages and monocytes.

Following synthesis, oligonucleotides are tested in an appropriate model system using optimal tissue or cell culture conditions. Inflammatory cells including lymphocytes, neutrophils, monocytes and macrophages are treated with the antisense oligonucleotides by the method of electroporation. Briefly, cells (5 X 10^6 cells in PBS) are transfected with oligonucleotides by electroporation at 200V, 1000 uF using a BTX Electro Cell Manipulator 600 (Genetronics, San Diego, CA). For an initial screen, cells are electroporated with 10 uM oligonucleotide and RNA is collected 24 hours later. Controls without oligonucleotide are subjected to the same electroporation conditions.

Total cellular RNA is then isolated using the RNEASY7 kit (Qiagen, Santa Clarita, CA). RNAse protection experiments are conducted using RIBOQUANT™ kits and template sets according to the manufacturer's instructions (Pharmingen, San Diego, CA).

Adherent cells such as endothelial and A549 cells are transfected using the LIPOFECTIN™ protocol described in Example 2. Reduced JNK mRNA expression is measured by Northern analysis while protein expression is measured by Western blot analysis, both described in Example 1. Negative control oligonucleotides with mismatch sequences are used to establish baselines and non-specific effects.

The degree of inflammatory response is measured by determining the levels of inflammatory cytokine expression by Northern or Western analysis, or cytokine secretion by enzyme-linked immunosorbent assay (ELISA) techniques. Enzyme-linked immunosorbent assays (ELISA) are standard in the art and can be found at, for example, Ausubel, F.M. et al., *Current Protocols in Molecular Biology*, Volume 2, pp. 11.2.1-11.2.22, John Wiley & Sons, Inc., **1991**.

The degree of inflammatory response is also determined by measuring the expression of known immediate-

early genes by the method of Northern or Western blot analysis. Further into the inflammatory response, levels of apoptosis are measured by flow cytometry as described in Example 10.

Example 13: Inhibition of fibrosis by antisense oligonucleotides targeting JNK family members

Pulmonary fibrosis is characterized by inflammatory and fibroproliferative changes in the lung and an excess accumulation of collagen in the interstitium. There is also an increased recruitment of immune and inflammatory cells to the lung which act not only in the initial damage to the lung but in the progression of the fibrotic process.

In the rodent bleomycin (BL)-induced pulmonary fibrosis model, inhibition of fibrosis in the lung is determined by measuring any of several markers for the condition. The BL-induced model is widely accepted in the art and can be found at, for example, Thrall, R.S. et al., Bleomycin In: *Pulmonary Fibrosis*, pp. 777-836, Eds. Phan, S.H. and Thrall, R.S., Marcel Dekker, New York, **1995** and Giri, S. N. et al., Miscellaneous mediator systems in pulmonary fibrosis In: *Pulmonary Fibrosis*, pp. 231-292, Eds. Phan, S.H. and Thrall, R.S., Marcel Dekker, New York, **1995.**

Antisense oligonucleotides targeting any of the JNK family members described in Examples 3-5 are synthesized and purified as in Example 1 and evaluated for their ability to prevent or inhibit pulmonary fibrosis. These fibrotic markers include release of various pro-inflammatory mediators including cytokines and chemokines such as TNFa, interleukin-8 and interleukin-6, increased numbers of proteases and metalloproteinases, generation of reactive oxygen species (ROS), edema, hemorrhage and

cellular infiltration predominated by neutrophils and macrophages.

Following synthesis, oligonucleotides are tested in the rodent BL-induced pulmonary fibrosis model using optimal conditions. Mice receive an intratracheal dose of bleomycin (0.125U/mouse) or saline, followed by treatment with antisense oligonucleotide (i.p.) over 2 weeks. After 2 weeks mice are sacrificed and biochemical, histopathological and immunohistochemical analyses are performed.

Biochemical and immunohistochemical analysis involves the measurement of the levels of pro-inflammatory cytokine expression by Northern or Western analysis, or cytokine secretion by enzyme-linked immunosorbent assay (ELISA) techniques as described in Example 12. Histopathological analyses are performed for the presense of fibrotic lesions in the BL-treated lungs and for the presence of and number of cells with the fibrotic phenotype by methods which are standared in the art.

Example 14: Sensitization to chemotherapeutic agents by antisense oligonucleotides targeting JNK family members

Manipulation of cancer chemotherapeutic drug resistance can also be accomplished using antisense oligonucleotides targeting JNK family members. Antisense oligonucleotides targeting any of the JNK family members described in Examples 3-5 are synthesized and purified as in Example 1 and evaluated for their ability to sensitize cells to the effects of chemotherapeutic agents. Sensitization is evident in the increased number of target cells undergoing apoptosis subsequent to treatment.

Following synthesis, oligonucleotides are tested in an appropriate model system using optimal tissue or cell culture conditions. Cells are treated with the compounds of the invention in conjunction with one or more chemotherapeutic

agents in a treatment regimen wherein the chemotherapeutic agents may be used individually (*e.g.*, 5-FU and oligonucleotide), sequentially (*e.g.*, 5-FU and oligonucleotide for a period of time followed by MTX and oligonucleotide), or in combination with one or more other such chemotherapeutic agents (*e.g.*, 5-FU, MTX and oligonucleotide, or 5-FU, radiotherapy and oligonucleotide).

For nonadherent cells, treatment is by the the method of electroporation. Briefly, cells (5 X 10^6 cells in PBS) are transfected with oligonucleotides by electroporation either before, during or after treament with the chemotherapeutic agent, at 200V, 1000 uF using a BTX Electro Cell Manipulator 600 (Genetronics, San Diego, CA). For an initial screen, cells are electroporated with 10 uM oligonucleotide and RNA is collected 24 hours later. Controls without oligonucleotide or chemotherapeutic agent are subjected to the same electroporation conditions.

Total cellular RNA is then isolated using the RNEASY7 kit (Qiagen, Santa Clarita, CA). RNAse protection experiments are conducted using RIBOQUANT™ kits and template sets according to the manufacturer's instructions (Pharmingen, San Diego, CA).

Adherent cells such as endothelial and A549 cells are transfected using the LIPOFECTIN™ protocol described in Example 2. Reduced JNK mRNA expression is measured by Northern analysis while protein expression is measured by Western blot analysis, both described in Example 1. Negative control oligonucleotides with mismatch sequences can be used to establish baselines and non-specific effects.

The degree of of apoptosis, and consequently sensitization is measured by flow cytometry as described in Example 10.